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Tennant

MINERALOGY AND CRYSTALLOGRAPHY:

BEING

A CLASSIFICATION OF CRYSTALS,

ACCORDING TO THEIR FORM;

AND

AN ARRANGEMENT OF MINERALS,

AFTER THEIR CHEMICAL COMPOSITION.

BY

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INTRODUCTORY NOTICE.

The following pages are intended to supply the student with an elementary treatise on the science of Crystallography, and a systematic arrangement and description of the various Minerals found in nature.

These treatises will, it is hoped, be found to contain all the information which can be required by a student wishing to master the elements of those sciences.

The various forms of Crystals are referred to six great classes or systems; under each system will be found a complete list of all the Minerals known to have assumed forms and faces belonging to it, together with the angular elements which determine their relation to their axes. Each form belonging to the system is then described; its mathematical properties discussed; simple geometrical constructions are given for modelling every variety which can occur in nature, as well as rules for representing them on paper, and laying down their poles on the sphere of projection or its map. This is followed by a list of all the species of the form which have been observed in the Mineral Kingdom, the symbols used by various authors for their description, and their respective angles.

All the important formulæ for the calculations of the angles of Crystals are given, and these formulæ are solved for nearly every case which has been recorded in the best and most recent works on Mineralogy. Indeed, it may be stated, with perfect propriety and truth, that this is the only treatise at all available to the student in which the systems of Crystallography are treated in a manner suitable for the class or lecture-room.

In the systematic description of the principal physical properties of Minerals, the chemical arrangement of the British Museum has been followed, as possessing great advantages for those who may avail themselves of the facilities afforded them in consulting one of the finest collections of Minerals in the world.

The student is thus presented with two distinct classifications of Minerals,—one in the Crystallography, according to the forms of their crystals, and the other following their chemical composition.

LONDON, *January*, 1856.

CRYSTALLOGRAPHY AND MINERALOGY.

CRYSTALLOGRAPHY, while it is of great value to the chemist and natural philosopher in their researches, is so important a branch of Mineralogy, that it is impossible to make any progress in that science without some knowledge of its principles. We therefore intend to make our Treatise on Crystallography serve as an introduction to Mineralogy. The hardness, specific gravity, chemical composition, and other properties of minerals, as well as the localities in which they are found, and their scientific arrangement, will follow the Treatise on Crystallography.

Crystallography.—In the mineral kingdom a great variety of solid bodies are met with, bounded by plane smooth surfaces. These bodies are called crystals, and it is the province of the science of Crystallography to investigate their mathematical properties, to classify and arrange them. The surfaces of crystals are not always plane; they are sometimes curved; but these curved surfaces are comparatively rare. Crystals are not confined to the mineral kingdom; they occur very frequently among the products of the chemical laboratory. Almost all the salts, and a great many other substances, under favourable circumstances, assume the form of crystals.

Some crystals are very simple in their forms, and present solids remarkable for their symmetry; while others are exceedingly complex, being bounded by more than a hundred different surfaces.

We are ignorant, as yet, of the manner in which the majority of crystals belonging to the mineral kingdom are formed. Very few can be reproduced by the chemist; and those which can, are generally smaller than the natural ones, and present few of their modifications. Crystals of quartz occur of an immense size in nature, some single crystals weighing many pounds. It is doubtful if any crystals of this substance have been obtained artificially. Crystals of carbonate of lime occur in nature of almost every size, and in almost numberless varieties of form; while the artificial crystals are almost microscopical in character. The diamond, which is carbon in a crystallized state, has never been produced by art; but some very minute crystals of a few of the other gems have been formed by the chemists.

Though we are ignorant of the means by which the great majority of crystals have been formed in the great laboratory of nature, we can crystallize an immense variety of substances. Nothing can be more interesting, and at the same time more instructive to the student of crystallography, than to watch the process of crystallization for himself, and observe the gradual growth of crystals.

Artificial Crystals.—Crystals may be obtained by various methods. Most of the salts, as well as some other substances which are soluble in water, deposit crystals as their solutions are gradually evaporated. Bismuth, and most other metals, assume the crystalline form as they pass from the fluid to the solid state after being melted. Some bodies become crystallized by the process of sublimation. Crystals are formed by the electro-galvanic decomposition of some solutions; thus, tin crystallizes by the reduction of a solution of its protochloride by a galvanic current. Crystals of sulphur may be obtained in three ways,—by sublimation, by the evaporation of its solution in bisulphide of carbon, and by cooling from a state of fusion.

Crystals, Crystalline, and Amorphous Substances.—All solid substances which do not owe their structure to the vital forces of the animal or vegetable kingdom are crystals, crystalline, or amorphous. Crystals have been already described. A crystalline body consists of a confused aggregation of minute or imperfect crystals; and an amorphous body is one in which, as its name implies, no form or structure can be observed. Sugar-candy consists of crystals of sugar; loaf-sugar is crystalline, and barley-sugar is amorphous. We meet with crystals of carbonate of lime in calcareous spar and arragonite; marble is a crystalline, and chalk an amorphous form of the same substance.

Faces, Edges, Angles, and Axes of Crystals.—The plane surfaces by which a crystal is bounded are called its faces. An edge is the line formed by the union of two faces. The solid angle of a crystal is produced by the union of more than two faces, and may be three-faced, four-faced, six-faced, &c. The plane angles are the angles on a face, bounded by the intersection of its boundary edges. Axes are imaginary lines, drawn through a crystal for the convenience of calculation, or for the purpose of describing its geometrical properties. Crystalline forms are the simplest mathematical solids in which crystals occur, or to which their faces are parallel.

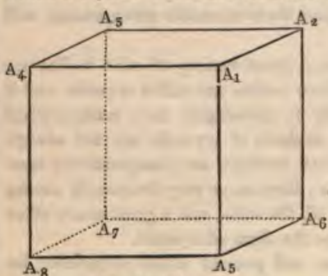


Fig. 1.—The Cube.

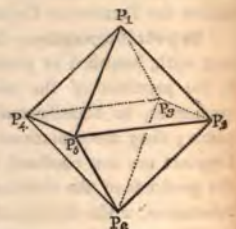


Fig. 2.—The Octahedron.

If as much common salt be thrown into boiling water as it will dissolve, beautiful cubes will be seen to form rapidly on its surface as it cools, as well as on the sides of the vessel in which it is contained. The same thing will occur more slowly, if a saturated solution of salt in cold water be allowed to evaporate spontaneously. A warm solution of alum will deposit octahedral crystals on strings suspended in it, as well as on the sides of the vessel containing it as it cools. The surfaces of the cube are all squares, those of the octahedron equilateral triangles; the cube is bounded by six squares, the octahedron by eight triangles.

Compound Crystalline Forms.—If an octahedral crystal of alum be left suspended, at the ordinary temperature of the atmosphere, for a day or two, in the solution of alum in which it was formed, though the crystal will increase in size, its form will generally be altered. The six solid angles, formed by the junction of four of the equilateral faces, will be found replaced by flat square surfaces; so that the crystal will present the appearance represented in Fig. 3, where the eight faces, bounded by six edges, and marked O_1, O_2, &c., O_8, will be parallel to those of the octahedron first formed by the solution.

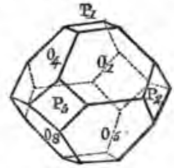


Fig. 3.

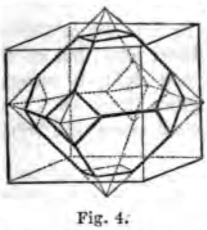


Fig. 4.

If the six square faces, marked P_1, P_2, &c., P_6, be produced till they intersect one another, these intersections will give the outline of a cube, while the faces O_1, O_2, &c., O_8, being similarly produced, will complete the figure of an octahedron, as shown by Fig. 4.

Such a crystal as this is called a combination of the forms of the cube and octahedron. The faces which, being produced, form a cube, are called the cubical faces; and those which form the octahedron, octahedral faces.

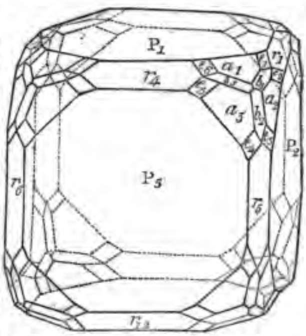


Fig. .

Far more complicated forms are found in nature. Fig. 5 represents a cube of fluor spar, every edge of which is modified or replaced by a plane surface, inclined to the sur-

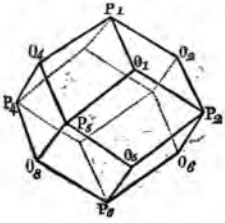


Fig. 6.
Rhombic Dodecahedron.

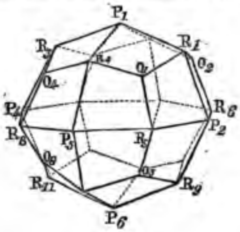


Fig. 7.
Twenty-four-faced Trapezohedron.

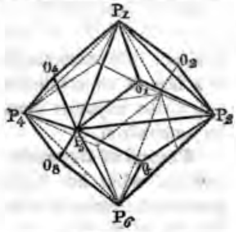


Fig. 8.
Three-faced Octahedron.

face of the cube; and every solid angle of the cube is replaced by twelve planes. The crystal has therefore one hundred and fourteen faces.

The six faces, P_1, P_2, P_3, &c., P_6, are parallel to the faces of the cube (Fig. 1).

The faces, r_1, r_2, r_3, &c., r_{12}, which replace the edges of the cube, are parallel to a twelve-faced figure, called the *Rhombic Dodecahedron* (Fig. 6).

The twenty-four faces a_1, a_2, a_3, &c., which modify each solid angle of the cube, are parallel to the surfaces of the twenty-four-faced trapezohedron, bounded by twenty-four similar and equal four-sided faces, called *deltoids*, or *trapeziums* (Fig. 7).

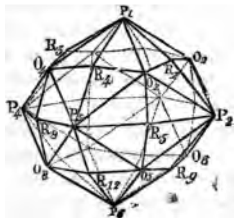


Fig. 9.—Six-faced Octahedron.

The twenty-four faces, b_1, b_2, b_3, &c., are parallel to the surfaces of the twenty-four-faced figure called the three-faced octahedron, each of whose faces is a similar and equal isosceles triangle (Fig. 8).

And the forty-eight faces, e_1, e_2, e_3, e_4, e_5, e_6, &c., are parallel to the surfaces of a forty-eight-faced figure, called the six-faced octahedron, each of whose faces are scalene triangles, similar and equal to each other (Fig. 9).

Modifications of Forms.—Crystals of simple forms, such as the octahedron, are sometimes formed with as much accuracy as the geometrical solid; but at other times the faces are so modified as to render it difficult, at first sight, to recognise the form to which they belong. The three accompanying figures (Figs. 10, 11, and 12) represent modifications of the octahedron frequently observed among the crystals

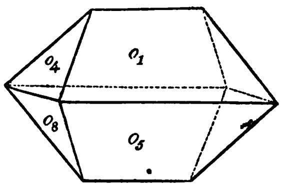


Fig. 10.

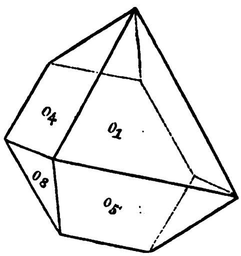


Fig. 11.

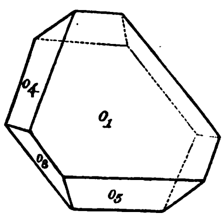


Fig. 12.

of alum. On examination, it will be found that the faces o_1, o_2, &c., o_8, are each parallel to a face of an octahedron; and that the inclination of any one face, such as o_1 on any of the adjacent faces, such as o_4, or o_5, is an angle of 109° 28′, as it is in the regular octahedron.

Forms of Crystals independent of the size of their Faces and Edges.—From what has been stated, with regard to the octahedron, it appears that the geometrical form, to which the faces of a natural crystal are referred, is independent of the size of the face, or even the form of its outline. Thus, the faces of an octahedron are all equilateral triangles, while some of the faces in the three preceding figures are bounded by four edges, as o_1 and o_5 (Fig. 10), o_4 and o_5 (Fig. 11), and some by six, as o_1 (Fig. 12). A regular octahedron, or cube, may be of any size, from one requiring a microscope to perceive it, to one whose edges are several inches in length. The faces of a compound crystal are always referred to the simplest symmetrical solid to which they are parallel. This parallelism is determined by the measurement of the inclination of one face to another. This inclination is determined by instruments called goniometers, which will be described hereafter.

Cleavage.—Some minerals are found to split, or cleave, with greater ease and readiness in some directions than others. In some cases, as in calcareous spar and fluor spar, this cleavage takes place with great facility, and displays very smooth surfaces. The cleavage is generally parallel to some crystalline form; that of calcareous spar being parallel to the six faces of a figure called the rhombohedron, and that of fluor spar parallel to the eight faces of the octahedron.

If a cube of fluor spar, A_1, A_2, &c., A_8, have diagonals, $A_1 A_3$, $A_2 A_4$, joining the opposite angles of its square faces, scratched upon them. It will be found that a knife being applied, with its edge on one of the diagonals $A_1 A_3$, and the blade of the knife in the same plane with the triangle $A_1 A_3 A_8$, a smart blow from a hammer, on the back of the knife, will detach the solid pyramid A_1 A_3 A_8 A_4, from the cube. In a similar manner, the pyramids A_1 A_3 A_6 A_2, A_1 A_8 A_6 A_5, and A_3 A_8 A_6 A_7, may be removed, leaving a regular tetrahedron, A_1, A_3, A_8, A_6, as the nucleus of the cube.

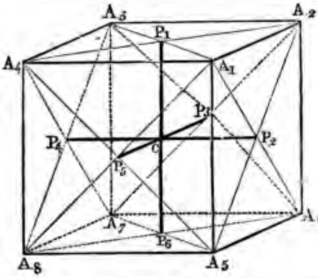


Fig. 13.

By removing the four pyramids whose vertices are, A_3, A_1, A_8, and A_6, another tetrahedron in the position A_2 A_4 A_7 A_5, might have been obtained.

Nature thus affords a demonstration of the 1st proposition of the 15th Book of Euclid—"*How to inscribe a regular Tetrahedron in a Cube.*"

By removing the eight solid pyramids, whose vertices are respectively A_1, A_2, &c., A_8, and replacing the removed fragments, we should see, within our transparent cube of fluor spar, a regular octahedron P_1 P_2 &c., P_6, inclosed within the cube, and regularly inscribed in it, as the octahedron is inscribed in a cube by the 3rd Prop. of the 15th Book of Euclid.

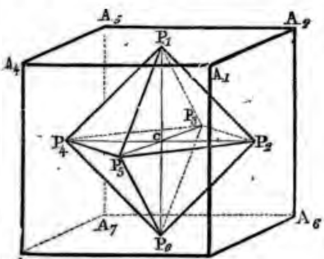


Fig 14.

Systems of Crystals.—We have seen that one substance, such as fluor spar, presents on its crystals faces parallel to several different mathematical symmetrical solid forms. All these forms can be shown to have certain mathematical relations to the cube or the regular octahedron. Other substances, whose crystals occur in the form of the cube or octahedron, or have faces parallel to these forms, present us with crystals either in the form, or with faces parallel to the same mathemathical solids.

These solids, thus associated in nature, and possessing certain mathematical properties in common, are classed together in one system, called the cubical or octahedral system.

Other substances occur in forms similar to, or with their faces parallel to, other mathematical solids, differing in their mathematical properties from those of the cubical system. These forms are classed together under other systems.

It may be observed, that faces parallel to the forms of one system are not found on the same crystal combined with faces parallel to the faces of forms belonging to a different system of crystallization. Thus, faces parallel to the eight faces of the regular octahedron are found on crystals, associated only with faces parallel to the forms of the cubical system, and not to forms belonging to the other systems.

Some one form may be taken as the type or primitive form, from which all others of the same system may be easily derived. This typical or primitive form is quite arbitrary; and it may be either a prism, an octahedron, or some other simple form.

1st system.—The cubical, or octahedral; according as we consider the regular cube or regular octahedron its typical or primitive form.

2nd system.—Square, prismatic, or pyramidal. Typical form, a prism on a square base, or octahedron on a square base.

3rd system.—Rhombohedral, or hexagonal. Typical form, the rhomboid or the hexagonal prism.

4th system.—Prismatic, or rhombic. Typical form, a right prism on a rhombic base, or octahedron on a rhombic base.

5th system.—Oblique. Typical form, an oblique prism on a rhombic base, or oblique pyramid on a rhombic base.

6th system.—Anorthic, or doubly oblique. Typical form, a doubly oblique prism or octahedron.

FIRST SYSTEM.—THE CUBICAL.

This system is called the *cubical* or *tesseral* (*tessera*, a cube), if its forms are regarded as derived from the cube; the *octahedral*, if its forms are derived from the regular octahedron. It is also called the *regular* or *isometrical*, from the properties of its axes.

The axes of this system will be described under the Cube.

The *holohedral forms* of this system, or those forms which possess the highest degree of symmetry, are the *cube*, *octahedron*, *rhombic*, *dodecahedron*, *three-faced octahedron*, *twenty-four-faced trapezohedron*, *four-faced cube*, and the *six-faced octahedron.*

From each of these, with the exception of the cube and rhombic dodecahedron, other forms are produced by the development of half their faces; these are called *hemihedral.*

The hemihedral form of the octahedron is the *tetrahedron*; that of the three-faced octahedron, the *twelve-faced-trapezohedron;* that of the twenty-four-faced trapezohedron, the *three-faced-tetrahedron*; and that of the four-faced cube the *pentagonal dodecahedron.* The six-faced octahedron has two hemihedral forms; the *six-faced tetrahedron* and a *twenty-four-faced trapezohedron* having two sides of its trapezoidal face parallel.

'^. two—the *pentagonal dodecahedron* and the *hemihedral twenty-four-faced tra-*

pezohedron—have their faces parallel to one another, in pairs, and are called *hemihedral forms with parallel faces.*

The other hemihedral forms are called *hemihedral forms with inclined faces.*

The Cube.—The cube or hexahedron (six-faced), is a solid bounded by six square faces; it has eight solid four-faced angles, A_1 A_2, &c., A_8 (Fig. 15), and twelve edges, $A_1 A_2$, $A_2 A_4$, &c. Every face is inclined to its adjacent faces at an angle of 90°.

Axes of the Cube and the Cubical System.

Cubical Axes.—If diagonals be drawn through the opposite angles of the faces

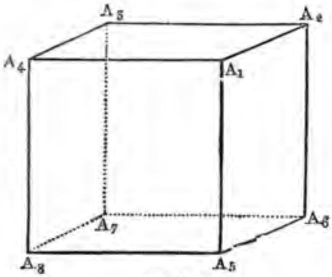


Fig. 15.

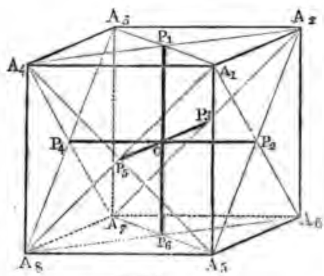


Fig. 16.

of the cube, they will intersect one another in the centre of each face. Let P_1, P_2, P_3, P_4 P_5 P_6 (Fig. 16), be these six centres.

Join $P_1 P_6$, $P_2 P_4$, and $P_3 P_5$.

These three lines will intersect one another in the point C. They are called the *regular or rectangular axes* of the cubical system.

Reckoning from C, which is the centre of the cube, each of the six lines, CP_1 CP_2, &c., CP_6, are equal to each other, and they are each perpendicular to a face of the cube at the point P, and the adjacent ones are inclined to each other at an angle of 90°.

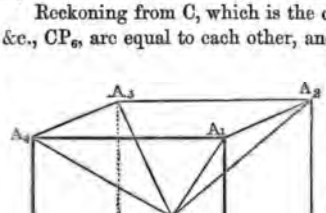


Fig. 17.

Octahedral Axes.—If lines be drawn from one solid angle of the cube to the solid angle opposite to it, we shall then have four lines, $A_1 A_7$, $A_2 A_8$, $A_3 A_5$, and $A_4 A_6$ (Fig. 17), intersecting one another at the same point, C, as the cubical axes. These lines are all equal, and inclined to one another at an angle of 70° 32′.

The eight lines CA_1 CA_2, &c., CA_8, are each perpendicular to a face of the octahedron inscribed in the cube. They are therefore called the *octahedral axes.* If $C P_1$ or $C P_2$ be taken as the unit, CA_1 CA_2, &c., will each be equal to $\sqrt{3}$.

Rhombic Axes—Let B_1 B_2 B_3, &c., B_{12}, be the centres of each of the twelve edges of the cube. Join B_1 B_{11}, B_2 B_{12}, &c. These six lines will intersect one another in C, the centre of the cube. Each of the lines CB_1 CB_2, &c., CB_{12}, are equal to one another, and perpendicular to a face of the rhombic dodecahedron inscribed in the cube. They are called the ***rhombic axes***, and the adjacent ones are inclined to each other at an angle of 60°. Taking CP_1, the cubical axis as = 1, CB_1, CB_2, &c., each $= \sqrt{2}$.

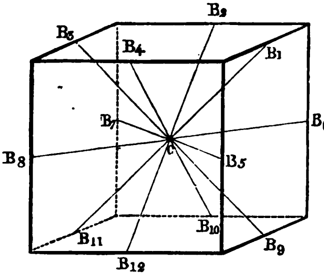


Fig. 18.

Normals.—A line drawn through a given point perpendicular to the face of a crystalline form, is called a *normal* to that face from the given point. Thus the cubical axes are normals to the faces of the cube from the point C, and the octahedral and rhombic axes are normals to the faces of the octahedron and rhombic dodecahedron from the same point.

To draw a Cube.—The perspective used in drawing crystals is called isometrical. In this, the lines which in the ordinary system of perspective are drawn converging to a point, are drawn parallel to one another. It is the most convenient method for representing geometrical solids.

Describe a square, A_1 A_5 A_8 A_4 (as at Figs. 2 and 15), of any convenient size. Draw the line A_1 A_2, at an angle of about 30° to the line A_1 A_4. Then, through A_4 A_5 and A_8 draw A_4 A_3, A_5 A_6, and A_8 A_7 parallel to A_1 A_2. Make A_1 A_2, A_4 A_3, A_5 A_6, and A_8 A_7 each half the length of one of the sides of the square A_1 A_5 A_4 A_8.

Join A_2 A_3, A_7 A_6, A_2 A_6, A_3 A_7, and the representation is completed.

Crystallographical Symbol for the Cube.—The relations of the faces of the cube to its *rectangular* or *cubical axes*, affords a ready means for adopting a symbol which shall express some of its properties. It will be readily seen that every face cuts one of the cubical axes, and is parallel to the directions of the other two. A line, or plane, which is parallel to another line or plane, is said, in mathematical language, to cut it at an infinite distance, and as ∞ is the symbol for infinity, regarding CP, the perpendicular distance of the cube from its centre as the unit, the symbol 1, ∞, ∞ signifies that every face of the cube cuts one of the axes at distance 1 from its centre, and the other two axes at an infinite distance. Naumann's symbol for the cube is $\infty O \infty$, Miller's, 100, and Brooke and Levy's modification of Haüy, P.

Generally in Naumann's symbols the figures represent the distances at which the faces of the form cut the rectangular axes, the figure 1 being always understood. In Miller's they signify the parts of some arbitrary unit, at which the faces cut the axes. In Brooke and Levy's, b^m indicates that every plane is parallel to an edge of the cube, m being the ratio which the two edges cut by the plane bear to one another; a^m and b^h b^k b^l represent that the planes are parallel to one cutting off a solid angle of the cube the figures m, h, k, and l, indicating the ratios of the cut edges of the solid angle.

Net for the Cube.—One of the simplest, most useful, and at the same time most inexpensive means of modelling the forms of crystals, is to draw their faces on pasteboard, and arrange them in such a manner that some of the edges being cut partially, and others quite through the pasteboard, the whole may readily fold up into the required form. The loose edges being glued together, a firm model will be formed in a few minutes. A drawing of the faces of a solid, arranged so that the model may be folded up from a single piece of pasteboard, is called *a net*.

To make a net for the cube, describe a square equal to a face of the required model, and arrange six such squares in the manner represented in Fig. 19. If a knife be drawn so as to cut the pasteboard half through along the light lines, and quite through along the dark ones, the figure will readily fold into the form of the cube.

In this and the other nets which will be described, it is very convenient to draw one face on tracing paper. The other faces may then be readily pricked off from this one on the pasteboard, in the required form, with greater ease, and even more accurately than by describing each face geometrically. It will also be found convenient to leave a margin to one edge where two edges are to be glued together. Glue is better than paste, as it dries more quickly, and does not, like paste or gum, warp the surfaces of the model.

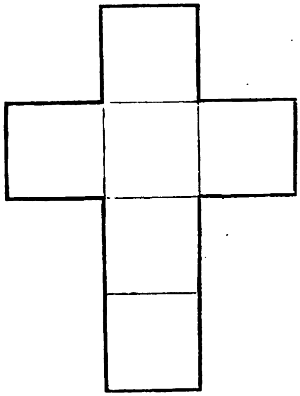


Fig. 19.

Minerals whose crystals occur in the form of the cube, or present, in their modifications, faces parallel to it:—

Alabandine (sulphuret of manganese).
Altaite (telluride of lead).
Alum.
Amalgam.
Analcime.
Argentite (sulphuret of silver).
Blende (sulphuret of zinc.
Boracite.
Bornite (purple copper).
Bromite.
Clausthalite (seleniuret of lead).
Cobaltine (bright white cobalt).
Copper.
Cubane.
Cuprite (red oxide of copper).
Diamond.
Embolite.
Eulytine (bismuth blende).
Fahlerz (gray copper).
Fluor.
Franklinite.
Gahnite (automalite).
Galena (sulphuret of lead).
Garnet.
Gersdorffite.
Gold.
Grünauite (sulphuret of nickel and bismuth).
Hauerite.
Hauyne.
Iridium.
Iron.
Iserine.
Kerate (muriate of silver).
Lerbachite (seleniuret of lead and mercury).
Linnéite (sulphuret of cobalt).
Magnetite (magnetic iron ore).
Naumannite.
Percylite.
Periclase.
Perowskite.
Petzite (telluride of silver).
Pharmacosiderite (arseniate of iron).
Platinum.
Pyrite (sulphuret of iron).
Pyrochlore.
Rammelsbergite (white arsenical nickel).
Safflorite (arsenical cobalt).
Sal ammoniac.
Salt.
Silver.
Skutterudite.
Smaltine (tin white cobalt).
Sodalite.
Stannine (sulphuret of tin).
Steinmannite.
Sylvine.
Tennantite.
Ullmanite (sulphuret of nickel and antimony).
Voltaite.

Minerals whose crystals cleave parallel to the faces of the cube,—those printed in italics *indicating that the cleavage is easy and perfect:—*

Alabandine.
Altaite.
Analcine.
Argentite.
Chromite.
Clausthalite.
Cobaltine.
Cubane.
Embolite.
Franklinite.
Gahnite.
Galena.
Gersdorffite.
Hauerite.
Iridium.
Iron.
Lerbachite.
Linnéite.
Magnetite.
Naumannite.
Periclase.
Perowskite.
Pyrite.
Pyrochlore.
Salt.
Skutterudite.
Smaltine.
Spinelle.
Stannine.
Steinmannite.
Sylvine.
Ullmanite.

The Octahedron—Called the regular octahedron, to distinguish it from other octahedrons, whose faces are not equilateral triangles. This form is bounded by eight equal and similar faces, each being an equilateral triangle. It has *twelve equal edges*, $P_1 P_2$, $P_2 P_3$, &c., and *six four-faced solid angles*, P_1 P_2 P_3 P_4 P_5, and P_6. Each face is inclined to its adjacent face at an angle of 109° 28.′

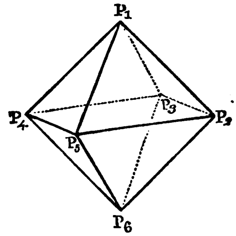


Fig. 20.

To draw the Octahedron—A cube being described as previously directed—

The centre of each face $P_1 P_2$, &c., P_6, may easily be found by joining $A_1 A_3$, $A_2 A_4$, &c. Join $P_1 P_6$, $P_2 P_4$, and $P_3 P_5$, meeting in C. These are the cubical axes of the cube. Join $P_1 P_2$, $P_1 P_3$, $P_1 P_4$, $P_1 P_5$, $P_2 P_3$, $P_3 P_4$, &c., as shown in Fig. 21, and an octahedron, $P_1 P_2$, &c., P_6, will be delineated inscribed in the cube; or two equal lines, $P_1 P_6$, and $P_2 P_4$ may be drawn perpendicular to one another, and intersecting each other in their centre C; draw CP_3, making an angle of 30° with CP_2, produce CP_3 to CP_5, and make CP_3, CP_5, each half of CP_2; and join the points $P_1 P_2$, &c., as before.

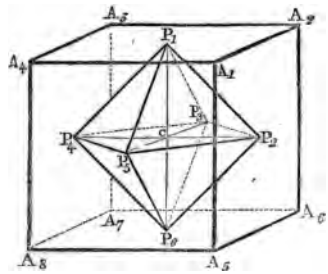


Fig. 21.

Relations of the Octahedron to the different Axes of the Cube.—From the previous figure it is evident that the cubical axes join the opposite solid angles of the octahedron.

Let $P_1 P_2 P_5$ (Fig. 22), be one of the faces of the octahedron. Bisect $P_1 P_2$, $P_2 P_5$, and $P_1 P_5$ in R_1, R_5 and R_4. Join $P_1 R_5$, $P_2 R_4$, and $P_5 R_1$.

These lines will intersect in O_1, and each of the lines RO will be one-third of the line PR.

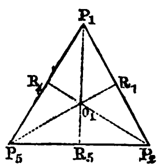


Fig. 22.

Suppose every face of the octahedron similarly divided, as shown in Fig. 23.

If now the octahedral axes $A_1 A_7$, $A_2 A_6$, &c., be drawn, joining the opposite solid angles of the cube, as in Fig. 17, each octahedral axis will pass through the face of the octahedron inscribed in the cube at the point O (Fig. 23), and will be perpendicular to it. The distance of O, from the centre of the cube, will be one-third of that of A; so that the octahedral axes of the octahedron will be a third of the octahedral axes of the cube in which it is inscribed.

The rhombic axes of the cube being drawn by joining the centres of its opposite edges, as in Fig. 18, these axes will pass through the centre of each edge of the octahedron, as R_1 R_4 and R_5 (Fig. 23). The distance of R, from the centre of the cube, will be one-half of that of B. Hence the rhombic axes octahedron will be one-half of the rhombic axes of the cube in which it is inscribed.

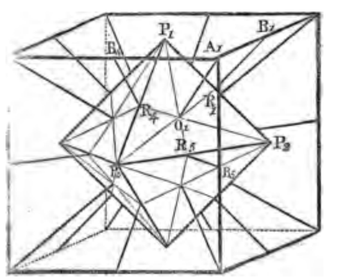


Fig. 23.

Symbols.—Each face of the octahedron cuts the three cubical axes at an equal distance CP from the centre of the cube, and taking CP as unity, 111 will be the symbol which expresses this relation of the faces of the octahedron to the cubical axes. Naumann's symbol for the octahedron is O, Miller's 111, and Brooke and Levy's modification of Haüy A^1 or a^1.

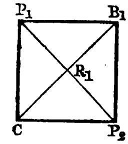


Fig. 24.

To describe a Net for the Octahedron.—If a model of a cube be formed by glueing the edges of six square pieces of glass, the different forms of the cubical system may be modelled of such a size as to be inscribed in the cube in the manner represented in their respective figures.

Describe a square P_1 B_1 P_2 C (Fig. 24), having its side P_1 B_1 equal to half the edge of the cube in which the model of the octahedron is to be inscribed.

Draw the diagonals P_1 P_2, and B_1 C; on either of these diagonals, as a base, describe an equilateral triangle (Fig. 22), and arrange eight such equilateral triangles, as in Fig. 25. When this net is cut out along the dark lines, and partially along the lighter lines, it will fold up into an octahedron, whose solid angles will just touch the centres of the faces of a cube the edge of which is twice the length of the line PB. In this and the following forms, the face of the crystal is described of such a size that the model may be inscribed in a cube whose edge is one inch in length. The faces on the net are only made half the size.

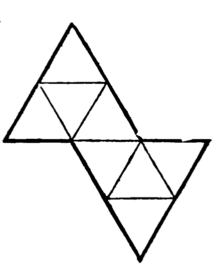


Fig. 25.

Minerals whose crystals occur in the form of the Octahedron, or whose modifications present faces parallel to it:—

Alabandine (sulphuret of manganese).
Alum.
Amalgam.
Argentite (sulphuret of silver).
Arquerite.
Arsenite (oxide of arsenic).
Blende (sulphuret of zinc).
Boracite.
Bornite (purple copper).
Bromite.
Chromite (chromate of iron).
Cobaltine (bright white cobalt).
Copper.
Cuprite (red oxide of copper).
Diamond.
Eisennickelkies.
Embolite.
Eulytine (bismuth blende).
Fahlerz (gray copper).
Fluor.
Franklinite.
Gahnite (automalite).
Galena (sulphuret of lead).
Gersdorffite.
Gold.
Grünauite (sulphuret of nickel and bismuth).
Hauerite.
Hauyne.
Helvin.
Iridium.
Irite.
Iron.
Iserine.
Kerate (muriate of silver).
Lead.
Linnéite (sulphuret of cobalt).
Magnetite (magnetic iron ore).
Mercury.
Palladium.
Pechuran (pitch blende).
Percylite.
Periclase.
Perowskite.
Pharmacosiderite (arseniate of iron).
Pyrite (sulphuret of iron).
Pyrochlore.
Rammelsbergite (white arsenical nickel).
Rhodizite.
Safflorite (arsenical cobalt).
Sal ammoniac.
Salt.
Senarmontite.
Silver.
Skutterudite.
Smaltine (tin white cobalt).
Spinelle.
Steinmannite.
Sylvine.
Tennantite.
Tritonite.
Ullmanite (sulphuret of nickel and antimony).
Uwarrowite.
Voltaite.

Minerals whose crystals cleave parallel to the faces of the Octahedron:—

Alum.
Arsenite.
Boracite.
Bornite.
Chromite.
Cuprite.
Diamond.
Eisennickelkies.
Fahlerz.
Fluor
Franklinite.
Gahnite.
Grünauite.
Magnetite.
Sal ammoniac.
Senarmontite.
Smaltine.
Spinelle.

Rhombic Dodecahedron.—The rhombic dodecahedron is a solid, bounded by twelve equal and similar four-sided figures, called *rhombs*. A *rhomb* is a figure such as $O_1 P_2 O_5 P_5$ (Fig. 26), which has all its sides equal, the angle at O_1 being equal to that at O_5, and that at P_2 to the angle at P_5. This form is sometimes called the *granatoëdron*, because it is a characteristic form of the *garnet*. The rhombic dodecahedron has *twenty-four equal edges*, $P_1 O_1$, $P_1 O_4$, &c., *six four-faced solid angles*, $P_1 P_2$, &c., P_6, and *eight three-faced solid angles*, $O_1 O_2$, &c., O_8. Each face is inclined to its adjacent faces at an angle of 160°; the great angle of the rhombic face as $P_2 O_1 P_5$, is 109° 28′, and the smaller angle, as $O_1 P_5 O_5$, is 70° 32′.

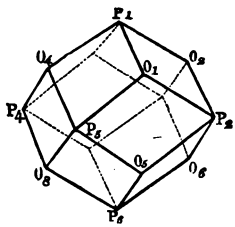


Fig. 26.

To draw the Rhombic Dodecahedron.—Describe a cube $A_1 A_2 A_3$ &c., A_8, (Fig. 27). Join $A_1 A_7$, $A_2 A_8$, &c., meeting in C.

Find P_1 the centre of the face $A_1 A_2 A_3 A_4$. Join CP_1 and $P_1 A_1$.

Bisect $A_1 B_5$ in E. Through E draw ED parallel to $P_1 A_1$, and cutting CA_1 in O_1.

Through O_1 draw $O_1 O_2$ parallel to $A_1 A_2$, cutting CA_2 in O_2, $O_2 O_3$ parallel to $A_2 A_3$, and $O_3 O_4$ parallel to $A_3 A_4$.

Also, through O_1 draw $O_1 O_5$ parallel to $A_1 A_5$, cutting CA_5 in O_5; draw $O_5 O_6$, $O_6 O_7$, and $O_7 O_8$ parallel to $A_5 A_6$, $A_6 A_7$, and $A_7 A_8$.

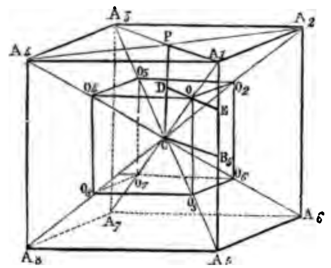


Fig. 27.

$O_1 O_2$ &c. O_8, will be the eight solid angles of a cube inserted in the cube $A_1 A_2$ &c. A_8, with the same centre, and having its edges half the length of the edges of $A_1 A_2$ &c. A_8.

$P_1 P_2$, &c., P_6 (Fig. 28, which are not marked on Fig. 27, to avoid crowding the figure), will be the six points where the six four-faced solid angles of the rhombic dodecahedron, inscribed in the cube $A_1 A_2$, &c., A_8, will touch its faces.

$O_1 O_2$, &c., O_8, the eight points where the octahedral axes of the cube pass through the eight three-faced solid angles of the inscribed rhombic dodecahedron.

Joining the lines $P_1 O_1$, $O_1 P_2$, $O_1 P_5$, &c., as shown in Fig. 29, the rhombic dodecahedron will be represented in perspective.

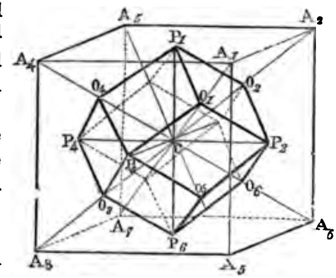


Fig. 28.

If the opposite angles of each face be joined, such as $O_1 O_2$, $P_1 P_2$, the rhombic axes of the cube will be found to pass through the intersection of these lines, and will also be perpendicular to the face through which they pass. The cubical axes of the rhombic dodecahedron are equal to the cubical axes of the cube, and join the opposite four-faced solid angles.

The octahedral axes of the rhombic dodecahedron are one-half the octahedral axes [illegible], *and join* the opposite three-faced solid angles.

The rhombic axes are half the rhombic axes of the cube in which it is inscribed, and join the centres of the opposite faces.

Symbols of the Rhombic Dodecahedron.—Each face of the rhombic dodecahedron cuts two of the cubical axes at equal distances from its centre, and the other at an infinite distance, or is parallel to it. Thus the face, P_1 O_1 P_2 O_2 cuts the axis CP_1 in P_1, and CP_2 in P_2, and is parallel to the axis CP_5. The symbol of the rhombic dodecahedron, which represents this relation of all it faces to the rectangular axes, is $1 1 \infty$. Naumann's symbol is ∞ O, Miller's 110, and Brooke and Levy's modification of Haüy, B^1 or b^1.

To describe the net of a Rhombic Dodecahedron which may be inscribed in a given cube.—Describe a square, P_1 B_1 P_2C, having its side equal to half the edge of the given cube. Join B_1 C, and P_1 P_2 meeting in R_1. Produce B_1 P_1 to A_1, and P_2 C to B_5. Make P_1 A_1, and CB_5, equal to CB_1, and CR_5 equal to CR_1.

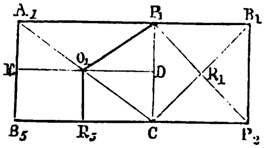


Fig. 29.

Join CA_1. Bisect A_1 B_5 in E. Through E draw EO_1D parallel to A_1 P_1, cutting A_1C in O_1. Join P_1 O_1, O_1 R_5.

P_1 A_1 B_5C represents the fourth part of the section of the cube, with its inscribed rhombic dodecahedron, through the lines A_1 A_3 A_7 A_5 (Fig. 28), and P_1 B_1 P_2C, the fourth part of the section, through the lines joining the points B_1 B_3 B_{11} B_9 (Fig. 18) of the cube.

To describe the face of the Rhombic Dodecahedron.—Draw a line, P_1 P_2 (Fig. 30), equal P_1 P_2 of Fig. 29. On it describe an isosceles triangle, having its sides P_1 O_1, P_2 O_1, equal P_1 O_1 of Fig. 29. Make a similar triangle P_1, O_2 P_2 on the other side of P_1 P_2. Then P_1 O_2 P_2 O_1 is the face of the rhombic dodecahedron, which may be inscribed in a cube whose edge is twice the length of P_1 B_1, or P_2 C of Fig. 29. Twelve of these rhombs, arranged as in Fig. 31, will give the required net of the rhombic dodecahedron.

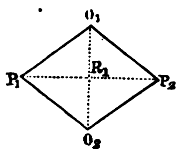


Fig. 30.

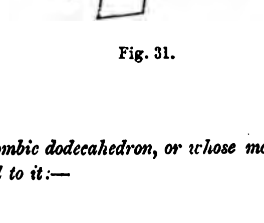


Fig. 31.

Minerals whose crystals occur in the form of the rhombic dodecahedron, or whose modifications present faces parallel to it:—

Alabandine (sulphate of magnesia.	Bornite (purple copper).	Franklinite.
Alum.	Cuprite (red oxide of copper).	Galena (sulphuret of lead.)
Amalgam.	Diamond.	Garnet.
Argentite (sulphuret of silver).	Dufrenoysite.	Gold.
Blende (sulphuret of zinc.)	Eulytine (bismuth blende).	Hauerite.
Boracite.	Fahlerz (gray copper).	Hauyne.
	Fluor.	Iserine.

Ittnerite.
Kerate (muriate of silver).
Leucite.
Magnetite (magnetic iron ore).
Percylite.
Perowskite.
Pharmacosiderite.
Pyrite (sulphuret of iron).
Pyrochlore.
Rammelsbergite (white arsenical nickel).
Rhodizite.
Sal ammoniac.
Salt.
Silver.
Skutterudite.
Smaltine (tin white cobalt).
Sodalite:
Spinelle.
Stannine (sulphuret of tin).
Tennantite.
Ullmanite (sulphuret of nickel and antimony.)
Voltaite.

Minerals whose crystals cleave parallel to the faces of the rhombic dodecahedron :—

Alabandine.
Amalgam.
Argentite.
Blende.
Eulytine.
Garnet.
Hauyne.
Ittnerite.
Leucite.
Skutterudite.
Smaltine.
Sodalite.
Stannine.
Tennantite.

The cube, octahedron, and rhombic dodecahedron, are the only forms parallel to which cleavages have been observed in crystals belonging to the cubical system.

Three-Faced Octahedron.—This figure, called also the *triakisoctahedron*, and by Haidinger, *galenoid*, as a characteristic form of *galena*, is a solid bounded by twenty-four isosceles triangles.

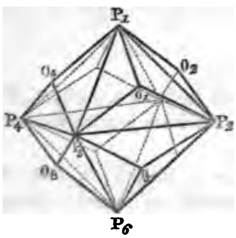


Fig. 32.

Solid Angles.—It has six eight-faced solid angles, P_1 P_2, &c., P_6; and eight three-faced solid angles, O_1 O_2, &c., O_8.

Edges.—There are twelve longer edges joining the eight-faced solid angles, $P_1 P_5$, $P_5 P_2$, $P_5 P_4$, &c., and twenty-four shorter edges joining each three-faced solid angle to three of the eight-faced solid angles O_1 P_5, O_1 P_2, O_1 P_1, &c.

An infinite number of varieties of this solid might exist; only seven different species have been observed in the mineral kingdom. The forms vary from that of the octahedron to the rhombic dodecahedron.

If a triangular pyramid, whose base is an equilateral triangle, and each of its faces an isosceles triangle, be applied to each face of a regular octahedron, the resulting form would be a three-faced octahedron. For every variation in height of this triangular pyramid as we may conceive it increasing in altitude, from the surface of the octahedron till it arrived at such a height that two adjacent triangular faces, such as P_1 O_1 P_5, and P_1 O_4 P_5, should lie in the same plane, when the figure would become a rhombic dodecahedron, we should have a distinct three-faced octahedron. When the three-faced octahedron is inscribed in the cube, the eight-faced solid angles touch the centre of each face of the cube, and the three-faced solid angles always lie in its octahedral axes.

Symbols of the Three-faced Octahedron.—Every face of this solid cuts two of the cubical axes passing through its centre, at a distance equal to that of its eight-faced solid angle from the centre, and the third axis produced at a greater distance. If the shorter distance be represented by 1, and the greater by *n*, where *n* may be any number or fraction greater than 1; 11*n* will be the symbol for the three-faced octahedron.

Naumann's symbol is nO; Miller's *hhk*, *h* being greater than *k*; and Brooke and T—v's modification of Haüy $A^{\frac{1}{n}}$ or $a^{\frac{1}{n}}$.

To draw the Three-faced Octahedron.—Let the figure be that whose symbol is $11n$. Describe a cube, A_1 A_2 A_3 &c., A_8 (Fig. 33). Let P_1 be the centre of the face A_1 A_2 A_3 A_4; B_5 the centre of the edge A_1 A_5. Take B_5 E equal the $\frac{n}{2n+1}$th part of B_5 A_1; that is if $n = 2$, as in the accompanying figure (Fig. 33), take B_5 E $= \frac{2}{5}$th of B_5 A_1. Through E draw E D, parallel to A_1 P_1, cutting A_1 C in O_1. Through O_1 draw O_1 O_2 parallel to A_1 A_2, O_2 O_3 parallel to A_2 A_3, &c., as in the preceding figure 27.

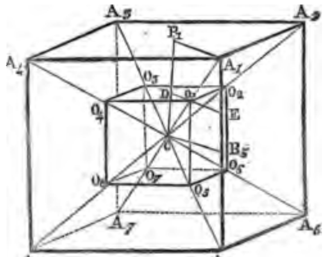


Fig. 33.

O_1 O_2 O_3 &c., O_8 will be the cube whose centre coincides with that of A_1 A_2, &c., A_8, and has its edge O_1 O_5 $= \frac{n}{2n+1}$th part of the edge A_1 A_5, O_1 O_2, &c., O_8 will be the points where the octahedral axes pass through the three-faced solid angles of the three-faced octahedron inscribed in the cube. Joining P_1 O_1, P_2 O_1, P_5 O_1, P_1 P_2, &c., as in Fig. 34, the three-faced-octahedron will be drawn inscribed in the cube.

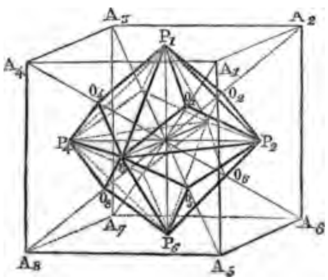


Fig. 34.

Axes.—The cubical axes of the three-faced octahedron are equal to those of the cube in which it is inscribed, and they join the opposite eight-faced solid angles.

The octahedral axes are $\frac{n}{2n+1}$th part of the octahedral axes of the cube, and join the opposite three-faced solid angles; and, as in the case of the octahedron, the rhombic axes are the half of the rhombic axes of the cube, and join the centres of the opposite longer edges.

As n varies from 1 when the three-faced octahedron coincides with the octahedron to ∞ when it coincides with the rhombic dodecahedron, the octahedral axes vary from the $\frac{1}{3}$rd to the $\frac{1}{2}$ of the octahedral axes of the cube, or the distance of the point O from C varies from the $\frac{1}{3}$rd to the $\frac{1}{2}$ of CA_1.

Inclination of the Faces of the Three-faced Octahedron.—If θ be the angle of inclination of any two adjacent faces, measured across the longer edge PP, then $\cos.\theta = \frac{2n^2-1}{2n^2+1}$, and if ϕ be the angle of two adjacent faces, measured across the shorter edge OP, $\cos.\phi = \frac{n(n+2)}{2n^2+1}$.

To describe a Net for the Three-faced Octahedron which may be inscribed in a given cube.—Describe a square, P_1 B_1 P_2 C (Fig. 35), having its sides equal to half the edge of the given cube. Join P_1 P_2, and B_1 C meeting in R_1. Produce B_1 P_1 to A_1, and P_2 C to B_5; make A_1 P_1 and B_5 C both equal to B_1 C. In

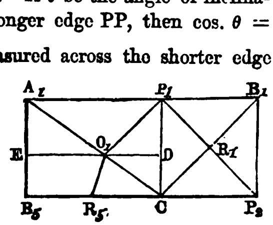


Fig. 35.

CB_3 make CR_3 equal to CR_1, join A_1C. Take CD equal to $\frac{n}{2n+1}$th part of CP_1, and through D draw DE, parallel to A_1P_1, cutting A_1C in O_1. Join P_1O_1, O_1R_5.

Take P_1P_2 (Fig. 36), equal P_1P_2 of Fig. 35, and on it, as a base, describe an isosceles triangle, $P_1\,O_1\,P_2$ having its sides $P_1\,O_1$, P_2, O_1, equal to $P_1\,O_1$ of Fig. 35.

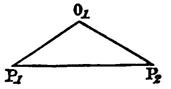


Fig. 36.

$P_1\,O_1\,P_2$ will be the face of the three-faced octahedron, which may be inscribed in the given cube. And twenty-four of these isosceles triangles, arranged as in Fig. 37, will form a net from which its model may be constructed.

Forms of three-faced Octahedron.—The three-faced octahedron, whose symbol is 112, 2 O of Naumann, 122 of Miller, and $a^{\frac{1}{2}}$ of Brooke and Levy, has its cubical axes equal those of the cube in which it is inscribed, its octahedral axes the $\frac{2}{3}$th, and its rhombic axes half those of the cube. Inclination of faces over shorter edge, 152° 44′, that of their normals 27° 16′; over the longer edge, 141° 3′, that of their normals, 38° 57′.

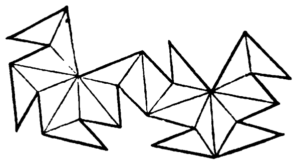


Fig. 37.

The following minerals present faces parallel to this form:—

Amalgam.	Fluor.	Pharmacosiderite
Argentite.	Franklinite.	Pyrite.
Blende.	Galena.	Skutterudite.
Cuprite.	Magnetite.	Spinelle.
Diamond.	Perowskite.	

The form 113, 3 O of Naumann, 133 of Miller, and $a^{\frac{1}{3}}$ of Brooke and Levy, has its octahedral axis equal $\frac{3}{7}$ths of those of the cube in which it is inscribed. Inclination of its faces over shorter edge, 142° 8′, that of their normals 37° 52′; over the longer edge 153° 28′, that of their normals, 26° 32′. Cuprite, Fluor, and Galena, are the only minerals which present faces of this form.

The form $11\frac{3}{2}$, $\frac{3}{2}$O of Naumann, 233 of Miller, and $a^{\frac{2}{3}}$ of Brooke and Levy, has its octahedral axes equal $\frac{3}{8}$ths of those of the cube in which it is inscribed. Inclination of faces over shorter edge, 162° 40′, that of their normals, 17° 20′; over the longer edge, 129° 31′, that of their normals, 50° 29′.

Faces of this form occur in Fahlerz and Garnet.

The form 114, 4 O of Naumann, 144 of Miller, and $a^{\frac{1}{4}}$ of Brooke and Levy. Octahedral axes $\frac{4}{9}$ths of those of the cube. Inclination of faces over shorter edge, 136° 39′; their normals, 43° 21′; over longer edge, 159° 57′, normals, 20° 3′.

Faces of this form have been observed in crystals of Galena and Kerate.

The form $11\frac{7}{4}$, $\frac{7}{4}$O of Naumann, 477 of Miller, and $a^{\frac{4}{7}}$ of Brooke and Levy, has its octahedral axis equal $\frac{7}{18}$th of those of the cube. Inclination of faces over shorter edge, 157° 5′, normals, 22° 55′; over longer edge, 136° 00, normals, 44°. Faces of this form have been observed on crystals of Galena.

The form $11\frac{5}{4}$, $\frac{5}{4}$0 of Naumann, 455 of Miller, and $a^{\frac{4}{5}}$ of Brooke and Levy, has its octahedral axis $\frac{5}{14}$ths of those of the cube. Inclination of faces over shorter edge, 170° 1′, normals, 9° 59′; over the longer edge 121° 00′, normals, 59° 00′. This form occurs in Galena.

The form $11\frac{65}{64}$, $\frac{65}{64}$O of Naumann, 64, 65, 65 of Miller, and $a\frac{64}{65}$ of Brooke and Levy, has its octahedral axes $\frac{65}{194}$th of those of the cube. Inclination of faces over shorter edge, 179° 17′, normals, 0° 43′; over longer edge, 110° 18′, normals, 69° 42′. This three-faced octahedron approximates very closely to the octahedron, and has only been observed on some crystals of Alum.

The Twenty-four Faced Trapezohedron.—This form is called the twenty-four-faced trapezohedron, or deltohedron, because it has twenty-four faces, each of the form of the figure called a deltoid or trapezium. It is known also by the names of the *icositessarahedron;* and being a characteristic crystal of the mineral leucite, it has been called *leucitoid.*

Faces.—This form is bounded by twenty-four equal and similar deltoids, or trapeziums, such as the figure $P_1 R_4 O_1 R_1$, which has the sides $P_1 R_4$ equal $P_1 R_1$, and $R_4 O_1 = R_1 O_1$, the angle $P_1 R_4 O$ = angle $P_1 R_1 O_1$, but the angle $R_4 P_1 R_1$ not equal to the angle $R_4 O_1 P_1$.

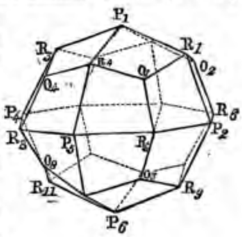


Fig. 38.

Solid Angles.—It has six four-faced solid angles, $P_1 P_2$, &c., P_6, which touch the centres of the faces of the cube in which it is inscribed, at the extremities of the cubical axes.

Twelve four-faced solid angles $R_1 R_2$, &c., R_{12}, which always lie in the rhombic axes of the cube in which it is inscribed. Eight three-faced solid angles, $O_1 O_2$, &c., O_8, which are always the octahedral axes of the cube in which it is inscribed.

Edges.—The edges are twenty-four longer, joining the four-faced solid angles, which terminate the cubical and rhombic axes, such as $P_1 R_1$, $P_1 R_2$, $P_1 R_3$, &c., and twenty-four shorter, joining the four-faced solid angles which terminate the rhombic axes to the three-faced solid angles which terminate the octahedral axes, as $O_1 R_1$, $O_1 R_4$, $O_1 R_5$, &c.

Symbols.—Every face of this form cuts one of the cubical axes at a distance from its centre, equal CP, and the other two axes produced at equal distances greater than CP.

Taking the lesser distance as 1, and the other two as m, where m may be any whole number or fraction greater than unity, the symbol which expresses this relation of the faces to the cubical axes will be $1mm$. Naumann's symbol is mOm; Miller's hhk, h being less than k; Brooke and Levy's modification of Haüy, A^m or a^m, where m is greater than 1.

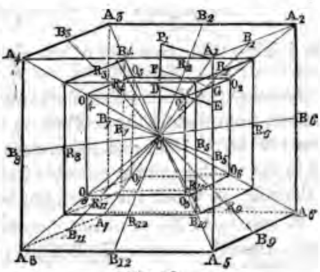


Fig. 39.

To Draw the Figure.—Describe a cube $A_1 A_2$, &c., A_7 (Fig. 39), with its cubical axes CP_1, CP_2, &c.; octahedral axes CA_1, CA_2, &c., and rhombic axes CB_1 CB_2, &c., CB_{12}.

Take E in $B_5 A_1$, so that $B_5 E = \frac{m}{m+2}$th part of $B_5 A_1$; and G, such that $B_5 G = \frac{m}{m+1}$th part of $B_5 A_1$.

Thus if $m = 2\,B_5\,E = \frac{2}{4}$ or $\frac{1}{2}$ of $B_5\,A_1$, and $B_5\,G = \frac{2}{3}$ of $B_5\,A_1$, if $m = 3\,B_5\,E = \frac{3}{5}$ of $B_5\,A_1$, and $B_5\,G = \frac{3}{4}$ of $B_5\,A_1$.

In CP_1 take $CD = B_5\,E$, and $CF = B_5\,G$. Join FG and DE, the latter cutting CA_1 in O_1.

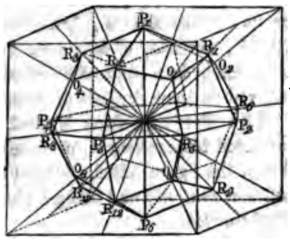


Fig. 40.

Through O_1 draw $O_1\,O_2$ parallel to $A_1\,A_2$, cutting CA_2 in O_2, $O_2\,A_3$ parallel to $A_2\,A_3$, cutting CA_3 in O_3, and so on till a cube $O_1\,O_2$, &c., O_8, is inscribed in the cube $A_1\,A_2$, &c., A_4 with its edges parallel to it.

Through the point where FG cuts CA_1, draw lines parallel to $A_1\,A_2$, and $A_1\,A_4$ to meet CA_2 and CA_4, and complete the cube, of which these two lines will be edges.

Let $R_1\,R_2$, &c., R_{12}, be the points where the lines CB_1, CB_2, &c., CB_{12}, cut the edges of this cube.

Now join the points PR and O as shown in Fig. 40, and the resulting form will be a representation of the twenty-four-faced trapezohedron inscribed in a cube.

Axes.—The cubical axes of this trapezohedron coincide with those of the cube in which it is inscribed, and join the opposite four-faced solid angles, $P_1\,P_2$, &c., P_6. The octahedral axes are the $\frac{m}{m+2}$th part of those of the cube, and join the opposite three-faced angles $O_1\,O_2$, &c., O_8.

The rhombic axes are the $\frac{m}{m+1}$th part of those of the cube, and join the opposite four-faced angles $R_1\,R_2$, &c., R_{12}.

Inclination of Adjacent Faces—If θ be the angle of inclination of two adjacent faces, measured over the edge PR, joining the extremities of the rhombic and cubical axes, $\cos.\,\theta = \frac{m^2}{m^2+2}$; and if ϕ be the angle of inclination measured over the edge OR, joining the extremities of the rhombic and octahedral axes, $\cos.\,\phi = \frac{2m+1}{m^2+2}$.

Limits of the Form.—This form varies as m increases from 1 to an infinitely great number, from that of the octahedron to that of the cube. In this case θ increases from 109° 28′ to 180°, and ϕ decreases from 180° to 90°; the octahedral axes from the $\frac{1}{3}$rd to the whole, and the rhombic from the $\frac{1}{2}$ to the whole of the corresponding axes of the cube, in which the figure can be inscribed.

To construct a Net of twenty-four-faced Trapezohedron, which can be inscribed in a given Cube.—Describe a square $P_1\,B_1\,P_2\,C$ (Fig. 41), having one of its sides equal half the edge of the given cube. Join CB_1, produce $P_2\,C$, and $B_1\,P_1$ to B_5 and A_1.

Make CB_5 and $P_1\,A_1$ equal CB_1. Join $A_1\,B_5$ and CA_1 Take $CD = \frac{m}{m+2}\,CP_1$, $CF = \frac{m}{m+1}\,CP_1$.

Draw DE and FG parallel to $A_1\,B_1$.

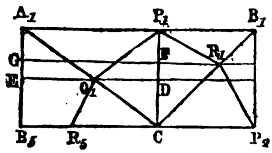


Fig. 41.

Let O_1 be the point where ED cuts A_1 C_1, and R_1 the point where FG cuts CB.

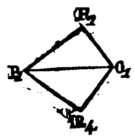


Fig. 42.

Take CR_5 in CB_5 equal to CR_1. Join P_1 R_1, R_1 P_2, P_1 O_1 and O_1 R_5.

Draw a line P_1 O_1 (Fig. 42), equal P_1 O_1 of Fig. 41, and on it describe a triangle having its sides P_1 R_1 and O_1 R_1 equal to P_1 R_1, and O_1 R_5 of Fig. 41. Describe a similar and equal triangle P_1 R_4 O_1 on the other side of P_1 O_1.

Then P_1 R_1 O_1 R_4 will be a face of the required twenty-four faced trapezohedron; and twenty-four of these being arranged as in Fig. 43, will form the net.

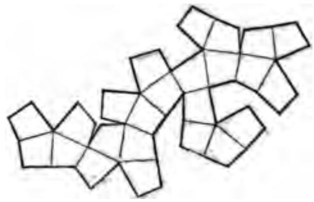


Fig. 43.

Forms of the Twenty-four faced Trapezohedron.—The form 122, 2 O 2 of Naumann, 112 of Miller, and a^2 of Brooke and Levy, has its octahedral axes $\frac{1}{2}$, and its rhombic axes $\frac{2}{3}$ of the corresponding axes of the cube in which it can be inscribed. Inclination of faces over any edge PR, 131° 49′, of their normals 48° 11′; over any edge OR 146° 27′, normals 33° 33′.

Crystals of the following minerals have faces parallel to this form:—

Amalgam.	Fahlerz.	Pyrite.
Argentite.	Franklinite.	Pyrochlore.
Analcime.	Fluor.	Sal ammoniac.
Boracite.	Gold.	Sodalite.
Cuprite.	Galena.	Smaltine.
Dufrenoysite.	Garnet.	Tennantite.
Eulytine.	Leucite.	

The form 133, 3 O 3 of Naumann, 113 of Miller, and a^3 of Brooke and Levy, has its octahedral axes $\frac{3}{5}$, and rhombic $\frac{3}{4}$ of those of the cube. Inclination over PR 144° 54′ normals, 35° 6′; over OR 129° 31′, normals 50° 29′. It occurs in

Blende.	Gold.	Perowskite.
Copper.	Galena.	Pyrochlore.
Fahlerz.	Magnetite.	Spinelle.
Fluor.	Pyrite.	

The form $1\,\frac{3}{2}\,\frac{3}{2}$, $\frac{3}{2}\,O\,\frac{3}{2}$, of Naumann, 223 of Miller, and $a^{\frac{3}{2}}$ of Brooke and Levy; octahedral axes $\frac{3}{7}$, rhombic $\frac{3}{5}$. Inclination over PR 121° 58′, normals 58° 2′; over OR 160° 15′, normals 19° 45′. It occurs in

Argentite, Gold, and Tennantite.

The form $1\,\frac{4}{3}\,\frac{4}{3}$, $\frac{4}{3}\,O\,\frac{4}{3}$ Naumann. 334 Miller, and $a^{\frac{4}{3}}$ Brooke and Levy, octahedral axes $\frac{2}{5}$, rhombic $\frac{4}{7}$. Inclination over PR 118° 4′, normals 61° 56′, over OR 166° 4′, normals 13° 56′. Occurs in Galena.

The form $1\,\frac{9}{4}\,\frac{9}{4}$, $\frac{9}{4}\,O\,\frac{9}{4}$ Naumann, 449 Miller, and $a^{\frac{9}{4}}$ Brooke and Levy, octahedral axes $\frac{9}{17}$, rhombic $\frac{9}{13}$. Inclination over PR 137° 48′, normals 44° 12′, over OR 141° 9′, normals 38° 51′. Occurs in Perowskite.

The form $1\,\frac{8}{3}\,\frac{8}{3}$, $\frac{8}{3}\,O\,\frac{8}{3}$ Naumann, 338 Miller, $a^{\frac{8}{3}}$ Brooke and Levy, octahedral axes $\frac{4}{7}$, rhombic $\frac{8}{11}$. Inclination over PR 141° 18′, normals 38° 42′; over OR 134° 2′, normals 45° 58′. Occurs in Fluor.

The forms 144, 1 10 10, 1 12 12, 1 16 16, and 1 40 40, whose octahedral axes are respectively $\frac{2}{3}$, $\frac{5}{6}$, $\frac{6}{7}$, $\frac{8}{9}$, and $\frac{20}{21}$, of those of the cube in which they are inscribed, and rhombic axes the $\frac{4}{5}$, $\frac{10}{11}$, $\frac{12}{13}$, $\frac{16}{17}$, and $\frac{40}{41}$. Their respective inclinations over PR being 152° 44′, 168° 38′, 172° 52′, and 177° 8′; over OR 120° 00′, 101° 53′, 99° 52′, 97° 21′, and 92° 54′, those of the normals of the former being 27° 16′, 11° 22′, 9° 30′, 7° 8′, and 2° 52′; of the latter 60° 00′, 78° 7′, 80° 8′, 82° 39′, and 87° 6′. 144 occurs in Kerate, 1 10 10, and 1 16 16 in Magnetite, 1 12 12 in Blende, and 1 40 40 in Pharmacosiderite.

The Four-Faced Cube, called also the *pyramidal cube* and *tetrakis-hexahedron*. Being a characteristic form of fluor spar, Haidinger gave it the name of *Fluoride*.

Faces.—This form is bounded by twenty-four equal and similar isosceles triangles. As the three-faced octahedron may be derived from the octahedron by placing on every face of the octahedron a pyramid with three triangular faces on a triangular base equal to the face of the octahedron, so this form may be derived from the cube by placing on every face of the cube a pyramid with four isosceles triangles for its faces, on a square base equal to the face of the cube.

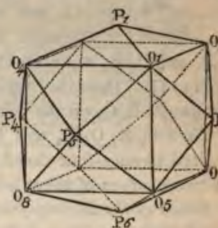


Fig. 44.

Solid Angles.—It has six four-faced solid angles, P_1 P_2, &c., P_6, which touch the centres of the faces of the cube in which it is inscribed, at the extremities of the cubical axes.

Eight six-faced solid angles, O_1 O_2, &c., O_8, which always lie in the octahedral axes of the cube in which it is inscribed.

Edges.—There are twelve longer equal edges (O_1 O_2, O_2 O_6, &c.) joining the six-faced solid angles together, and twenty-four shorter equal edges, P_1 O_1, P_1 O_2, &c., joining the four-faced solid angles with the six-faced ones.

Symbols.—Every face of this form cuts one of the cubical axes at a distance, CP (Fig. 45), from its centre, another axis at a distance m times CP from the centre, and is parallel to the third axis; m may be any whole number or any fraction greater than one. Taking CP = 1, the symbol which will represent this relation is $1\ m\ \infty$. Naumann's symbol is ∞Om, Miller's hko, and Brooke and Levy's modification of Hauy, b^m or B^m.

To draw the Four-faced Cube.— Describe a cube A_1 A_2, &c., A_8 (Fig. 45), with its octahedral axes A_1 A_7, A_2 A_8, &c., meeting in C, and its rhombic axes B_1 B_{11}, B_3 B_9, &c.

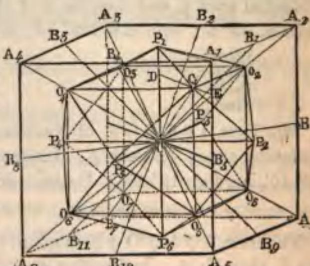


Fig. 45.

Take E in B_5 A_1, so that $B_5\,E = \frac{m}{m+1}\,CA_1$.

Thus, if $m = 2$ $B_5E = \frac{2}{3}\,CA_1$.

Thus, if $m = 3$ $B_5E = \frac{3}{4}\,CA$.

In CP_1 take $CD = B_5\,E$. Join DE, cutting CA_1 in O_1.

Through O_1 draw O_1 O_2 parallel to A_1 A_2, cutting CA_2 in O_2. Through O_2 draw O_2 O_3 parallel to A_2 A_3, cutting CA_3 in O_3; and so on, till a cube O_1 O_2, &c., O_8, is inscribed in the cube A_1 A_2, &c., A_8, with its edges parallel to it.

Join the points P_1 O_1, P_1 O_2, &c., as in Fig. 45, and the resulting figure will be a representation of the four-faced cube inscribed in a cube.

Axes.—The cubical axes, P_1 P_6, P_2 P_4, and P_5 P_3 of the four-faced cube coincide with those of the cube in which it is inscribed, and join the opposite four-faced solid angles, $P_1 P_2$, &c., P_6.

The octahedral axes are the $\frac{m}{m+1}$th part of those of the cube, and join the opposite six-faced solid angles, $O_1 O_2$, &c., O_8.

The rhombic axes are the $\frac{m}{m+1}$th part of those of the cube, and join the centres of the opposite longer edges, $O_1 O_2$, $O_8 O_7$, &c.

Inclination of Adjacent Faces.—If θ be the angle of inclination of two adjacent faces, measured over the edge, joining the extremities of the octahedral axes, such as $O_1 O_2$, $\cos. \theta = \frac{2m}{1+m^2}$; and if ϕ be the angle of inclination measured over the edge joining the extremities of the octahedral axes with those of the cubical, such as $P_1 O_1$, then $\cos. \phi = \frac{m^2}{1+m^2}$.

Limits of the Form.—The four-faced cube varies as m increases in magnitude, from 1 to ∞, from the rhombic dodecahedron to the cube. In this case θ decreases from 180° to 90°, and ϕ increases from 120° to 180°. The octahedral and rhombic axes increase from the $\frac{1}{2}$ to the whole of the corresponding axes of the cube in which the figure can be inscribed.

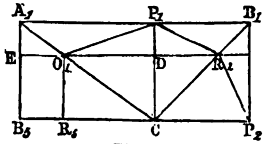


Fig. 46.

To construct a Net of the four-faced Cube which can be inscribed in a given Cube.

Describe a square, $P_1 B_1$, $P_2 C$ (Fig. 46), having one of its sides equal half the edge of the given cube.

Join CB_1. Produce $P_2 C$, and $B_1 P_1$ to B_5 and A_1. Make CB_5 and $P_1 A_1$ both equal CB_1.

Join $A_1 B_5$, and $A_1 C$.

Take $B_5 E = \frac{m}{m+1} A_1 B_5$.

Through E draw ED parallel $A_1 P_1$, cutting $A_1 C$ in O_1. Join $P_1 O_1$.

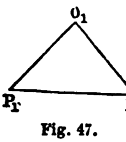


Fig. 47.

Draw a line, $P_1 P_2$ (Fig. 47), equal CB_1, or $P_1 P_2$ of Fig. 46. On this base describe an isosceles triangle $O_1 P_1 P_2$, having each of its sides, $P_1 O_1$, $O_1 P_2$, equal $P_1 O_1$ of Fig. 46.

$P_1 O_1 P_2$ will be a face of the required four-faced cube; twenty-four of these faces being arranged together, as in Fig. 48, will form the required net.

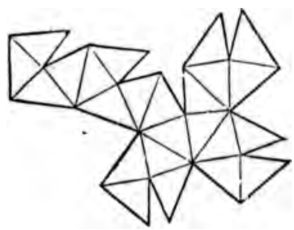


Fig. 48.

Forms of the four-faced cube.

The form 12∞, $\infty O2$ of Naumann, 210 Miller, and b^3 of Brooke and Levy, has its octahedral and rhombic axes $\frac{2}{3}$ of those of the cube in which it is inscribed. Inclination of faces over any edge, such as $O_1 O_2$ 143° 8′ of their normals 36° 52′; over any edge, such as $P_1 O_1$ 143° 8′ normals 36° 52′.

Crystals of the following minerals have faces parallel to this form:—

Argentite.	Fluor.	Garnet.	Percylite.
Copper.	Gold.	Magnetite.	Salt.
Cobaltine.	Gersdorffite.	Pyrite.	Silver.
Cuprite.			

The form 13∞, $\infty O3$ Naumann, 310 Miller, b^3 Brooke and Levy, has its octahedral and rhombic axes $\frac{3}{4}$ of the cube; inclination over O_1O_2 126° 52′, normals 53° 8′; over P_1O_1 154° 9′, normals 25° 51′. It occurs in

Amalgam, Fahlerz, Fluor, Hanerite, and Pyrite.

The form $1\frac{3}{2}\infty$, $\infty O\frac{3}{2}$ Naumann, 320 Miller, $b^{\frac{3}{2}}$ Brooke and Levy, has its octahedral and rhombic axes $\frac{3}{5}$ of the cube, inclination over O_1O_2 157° 23′, normals 22° 37′; over P_1O_1 133° 49′, normals 46° 11′. It occurs in

Argentite, Blende, Diamond, Pyrite, and Perowskite.

The form $1\frac{5}{2}\infty$, $\infty O\frac{5}{2}$Naumann, 520 Miller, $b^{\frac{5}{2}}$ Brooke and Levy, has its octahedral and rhombic axes $\frac{5}{7}$th those of the cube, inclination over O_1O_2 133° 56′, normals 46°24′; over P_1O_1 149° 33′, normals 30° 27′. It occurs in

Copper and Fluor.

The form $1\frac{4}{3}\infty$, $\infty O\frac{4}{3}$ Naumann, 430 Miller, and $b^{\frac{4}{3}}$ Brooke and Levy, has its octahedral and rhombic axes $\frac{4}{7}$th those of the cube, inclination over O_1O_2 163° 44′, normals 16° 16;′ over P_1O_1 129° 48′, normals 50° 12′. It occurs in

Diamond and Perowskite.

The form 14∞, $\infty O4$ Naumann, 410 Miller, and b^4 Brooke and Levy, has its octahedral and rhombic axes $\frac{4}{5}$ of the cube, inclination over $O_1\,O_2$ 118° 4′, normals 61° 56′; over $P_1\,O_1$ 160° 15′, normals 19° 45′. It occurs in

Cobaltine and Silver.

The form $1\frac{5}{4}\infty$, $\infty O\frac{5}{4}$ Naumann, 540 Miller, $b^{\frac{5}{4}}$ Brooke and Levy, has its octahedral and rhombic axes $\frac{5}{9}$th of the cube, inclination over edge O_1O_2 167° 19′, normals 12° 41′; over edge $P_1\,O_1$ 127° 34′, normals 52° 26′. It occurs in

Perowskite.

The form 15∞, $\infty O5$ Naumann, 510 Miller, b^5 Brooke and Levy, has its octahedral and rhombic axes $\frac{5}{6}$ of the cube, inclination over $O_1\,O_2$ 112° 38′, normals 67° 42′, over $P_1\,O_1$ 164° 4′, normals 25° 51′. It occurs in

Cuprite.

The form $1\frac{5}{4}\infty$ approaches nearer to the rhombic dodecahedron, and the form 15∞ to the cube, than any of the other forms which have been described as occuring in nature.

Six-faced Octahedron.—The six-faced octahedron, called also the *hexakisoctahedron*, *tetra-kontaoktaèdron*, *pyramidal-granatohedron*, *triagonal polyhedron*. Being a characteristic form of the diamond, Haidinger named it *Adamantoid*.

Faces, Edges, and Solid Angles.—The six-faced octahedron is bounded by forty-eight equal and similar scalene triangles, such as $P_1\,O_1\,R_1$, $P_1\,O_1\,R_4$, &c. It has six eight-faced solid angles, P_1 P_2, &c., P_6, whose apices terminate the cubic axes and touch the faces of the cube in which the figure can be inscribed. Eight six-faced solid angles, O_1 O_2, &c., O_8, whose apices always lie in the octahedral axes, and twelve four-faced solid angles, R_1 R_2 R_3, &c., R_{12}, whose apices always lie in the rhombic axes of the cube in which the six-faced octahedron can be inscribed. It has twenty-four long edges, $P_1\,O_1$, $P_1\,O_2$, &c., $P_6\,O_8$, joining the apices of the eight-faced and six-faced solid angles, twenty-four intermediate edges, $P_1\,R_4$, $R_4\,P_5$, &c., joining the apices of the eight-faced and four-faced solid angles, and twenty-four short edges, $O_1\,R_1$, $O_1\,R_4$, $O_1\,R_5$, &c., joining the apices of the six-faced and four-faced solid angles.

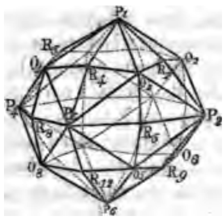


Fig. 49.

Symbols for the Six-faced Octahedron.—Every face of the six-faced octahedron, if produced, will cut three of the cubical axes produced in three points at unequal distances from the centre of the axes. Thus, in Figs. 49 or 50, the face $O_1\,R_5\,P$ produced cuts the axis $C\,P_2$ at the point P_2, the axis $C\,P_5$ produced at a distance $\frac{3}{2}$ of $C\,P_5$, and $C\,P_1$ produced at a distance three times $C\,P_1$ from C, the centre of the axes and figure. Similarly, every face of the figure cuts one axis at a distance C P, another produced at $\frac{3}{2}$ of C P, and the third cubical axis produced at a distance three times C P. Taking C P, the distance of the centre of the figure from the apex of one of its eight-faced solid angles, as our unit, the symbol which will represent this relation of the faces to the cubical axes will be 1, $\frac{3}{2}$, 3. The general symbol will be 1, m, n, where m and n are any whole numbers or fractions greater than one, and m less than n.

Naumann's symbol is $m\,O\,n$, Miller's $h\,k\,l$, h, k and l being all three whole numbers; and Brooke and Levy's modification of Haüy, $B^{\frac{1}{h}}\ B^{\frac{1}{k}}\ B^{\frac{1}{l}}$ or $b^{\frac{1}{h}}$, $b^{\frac{1}{k}}$, $b^{\frac{1}{l}}$.

To draw the Six-faced Octahedron, whose symbol is 1, m, n.

Describe a cube $A_1\,A_2$, &c., $A_7\,A_8$ (Fig. 50) with its octahedral axes, $C\,A_1$, $C\,A_2$, &c. $C\,A_8$, rhombic axes $C\,B_1$, $C\,B_2$, &c. $C\,B_{12}$, and cubic axes $C\,P_1$, $C\,P_2$, &c. $C\,P_6$; only one of the latter, $C\,P_1$, is shown in Fig. 52, in order not to crowd the figure unnecessarily.

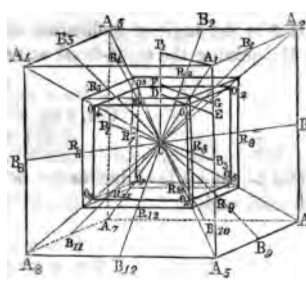


Fig. 50.

Take a point E in $B_5\,A_1$, such that

$$B_5\,E = \frac{1}{1+\frac{1}{m}+\frac{1}{n}}\,B_5\,A_1$$

For the form 1, $\frac{3}{2}$, 3 $B_5\,E = \frac{1}{1+\frac{2}{3}+\frac{1}{3}}$ $B_5\,A_1 = \frac{1}{2}\,B_5\,A_1$, or $B_5\,E = \frac{1}{2}\,B_5\,A_1$.

Take another point G in $B_5\,A_1$, such that

$$B_5\,G = \frac{1}{1+\frac{1}{m}}\,B_5\,A_1.$$

For the form 1, $\frac{3}{2}$, 3 $B_5\,E = \frac{1}{1+\frac{2}{3}}\,B_5\,A_1 = \frac{3}{5}\,B_5\,A_1$.

Join $P_1\,A_1$ and $C\,B_5$; through E and G, draw E D, and E F parallel to $A_1\,P_1$ or $B_5\,C_2$ Let E D cut $C\,A_1$ in O_1. Through O_1 draw O_2 parallel to $A_1\,A_2$, cutting $C\,A_2$

in O_2; $O_2\,O_3$ parallel to $A_2\,A_3$, cutting C A_3 in O_3, and so on, till a cube $O_1\,O_2$, &c., O_8, is inscribed in $A_1\,A_2$, &c., A_8; having C O_1 C O_2, &c., C O_8 for its octahedral axes.

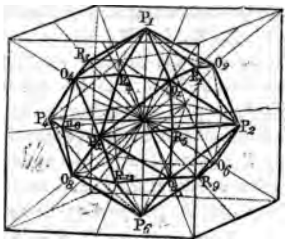


Fig. 51.

Similarly, commencing from the point where F G cuts C A_1, draw another cube whose edges are parallel to the one just described, and having C R_1, C R_2, C R_3, &c., C R_{12} for its rhombic axes, as shown in Fig. 50. Join the points $P_1\,O_1$, $O_1\,R_4$, $P_1\,R_4$, &c., as shown in Fig. 51, and the six-faced octahedron will be drawn, with all its axes inscribed in a cube. In this, as in the preceding forms, if it is only required to show the form itself, as in Fig. 49, the Figure 51 may be first drawn in pencil, and the outlines of the form being drawn in ink, the other lines may be rubbed out. The form drawn in Figs. 49 and 51 is that whose symbol is 1, $\frac{3}{2}$, 3, but the student is advised to draw for himself some of the other forms which occur in nature of the six-faced octahedron, in order to familiarise himself with the different properties of the figure, and its relations to the axes of the cube in which it is inscribed.

Axes of the Six-faced Octahedron.

The cubical axes of the six-faced octahedron join the opposite eight-faced solid angles, and are equal to the cubical axes of the cube in which it is inscribed.

The octahedral axes join the opposite six-faced solid angles, and are equal to the $\dfrac{1}{1+\frac{1}{m}+\frac{1}{n}}$th part of the octahedral axes of the cube in which the figure is inscribed.

The rhombic axes join the opposite four-faced solid angles, and are equal to the $\dfrac{1}{1+\frac{1}{m}}$th part of the rhombic axes of the cube in which the figure is inscribed.

Inclination of the Adjacent Faces.

If θ be the angle of inclination of two adjacent faces over the edge P O (Figs. 49 and 51), joining the eight-faced and six-faced solid angles,

$$\text{Cos. } \theta = \frac{1+\frac{2}{m\,n}}{1+\frac{1}{m^2}+\frac{1}{n^2}}.$$

If ϕ be the angle of inclination over the edge OR, joining the six-faced and four-faced solid angles,

$$\text{Cos. } \phi = \frac{\frac{2}{m}+\frac{1}{n^2}}{1+\frac{1}{m^2}+\frac{1}{n^2}}.$$

If ψ be the angle of inclination over the edge RP, joining the four-faced and eight-faced solid angles,

$$\text{Cos. } \psi = \frac{1+\frac{1}{m^2}-\frac{1}{n^2}}{1+\frac{1}{m^2}+\frac{1}{n^2}}.$$

Limits of the Form of the Six-faced Octahedron.

The six-faced octahedron may be regarded as the most general form of the cubical system, and that from which all the others may be easily derived, Thus, as m and n approach in magnitude to unity, the *six-faced octahedron* approximates to the *octahedron;* and when m and n are both equal to unity, it becomes the *octahedron.* In this case, the six faces forming the six-faced solid angle all lie in the same plane, and the edges $P_1 R_4$ and $R_5 P_6$ lie in the same line.

As m and n both increase in magnitude and in equality to each other, the *six-faced octahedron* approximates to the *cube;* and when m and n are both infinitely great it becomes the *cube.* In this case, the eight planes which form each eight-faced solid angle all lie in the same plane, and the edges $O_1 R_4$ and $R_4 O_4$ lie in the same line.

As m approaches to unity while n increases in magnitude, the *six-faced octahedron* approximates to the *rhombic dodecahedron;* and when m equals unity, and n is infinitely great, it becomes the *rhombic dodecahedron.* In this case, the four planes which form each four-faced solid angle lie in the same plane.

When m equals unity while n remains finite, the *six-faced octahedron* becomes the *three-faced octahedron;* and the planes on each side of the edge RO lie in the same plane.

When m and n are equal to each other, both finite and greater than unity, the *six-faced octahedron* becomes the *twenty-four-faced trapezohedron;* and the planes on each side of the edge PO lie in the same plane.

When m remains finite, and n becomes infinite, the *six-faced octahedron* becomes the *four-faced cube,* and the planes on each side of the edge PR lie in the same plane.

All the formula for the axes and the inclination of the faces, &c., for all the holohedral forms of the cube may be derived from those of the six-faced octahedron, by substituting $\frac{1}{0}$ for m and n, for the cube; 1 for m and n for the octahedron; 1 for m and $\frac{1}{0}$ for n for the rhombic dodecahedron; 1 for m for the three-faced octahedron; m for n for the twenty-four-faced trapezohedron; and $\frac{1}{0}$ for n for the four-faced cube.

To describe a Net for the Six-faced Octahedron which may be inscribed in a given Cube.

Describe a square, $P_1 B_1 P_2 C$ (Fig. 52), having one of its sides half the edge of the given cube. Join CB_1.

Produce $B_1 P_1$ to A_1, and $P_2 C$ to B_5.

Make $A_1 P_1$ and $C B_5$ both equal $C B_1$. Join $A_1 B_5$ and $A_1 C$.

Take $B_5 E = \dfrac{1}{1 + \frac{1}{m} + \frac{1}{n}} B_5 A_1$ and $B_5 G = \dfrac{1}{1 + \frac{1}{m}} B_5 A_1$.

Through G and E draw G F and E D parallel to $A_1 P_1$.

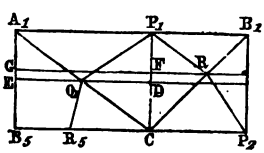


Fig. 52.

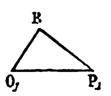


Fig. 53.

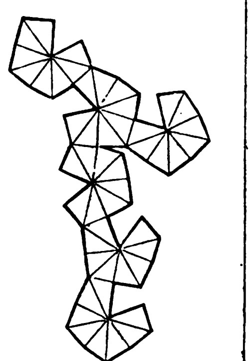


Fig. 54.

Let E D cut $A_1 C$ in O_1, and G F produced cut $C B_1$ in R_1. Join $P_1 O_1$, $P_1 R_1$, and $R_1 P_2$.

In C B_5 take C R_5 equal C R_1 and join R_5 O_1.

Then draw a line O_1 P_1 (Fig. 53), equal O_1 P_1 (Fig. 52) on O_1 P_1 (Fig. 53), as a base, describe a triangle, O_1 R P_1, having its side O_1 R equal to O_1 R_5 (Fig. 52), and the side P_1 R equal to P_1 R_1 of Fig. 52, then O_1 R P_1 will be a face of the required figure.

Forty-eight such faces arranged together, as in Fig. 54, will form the required net from which a model of the six-faced octahedron can be formed, which can be inscribed in the given cube.

Forms of the Six-faced Octahedron which occur in Nature.

The form 1, $\frac{5}{4}$, $\frac{5}{3}$ whose symbols are $\frac{5}{3}$ O $\frac{5}{4}$, Naumann; 5, 4, 3, Miller; and $b^{\frac{1}{5}}$, $b^{\frac{1}{4}}$, $b^{\frac{1}{3}}$, Brooke and Levy, has its octahedral axes $\frac{5}{12}$th and rhombic $\frac{5}{8}$th those of the cube in which it is inscribed.

Cos. $\theta = \frac{49}{50}$ $\theta = 168° \, 31'$, cos. $\phi = \frac{49}{50}$ $\phi = 168° \, 31'$ cos. $\psi = \frac{32}{50}$ $\psi = 129° \, 48'$.

Inclination of normals of faces whose inclinations to each other are θ ϕ and ψ respectively, 11° 29′, 11° 29′, and 50° 12′.

Faces parallel to this form occur in crystals of Pyrite.

The form 1, $\frac{64}{63}$, 64 ; 64 O $\frac{64}{63}$, Naumann; 64, 63, 1, Miller; b^1, $b^{\frac{1}{63}}$, $b^{\frac{1}{64}}$, Brooke and Levy. Octahedral axes $= \frac{1}{2}$; rhombic $= \frac{64}{127}$.

Cos. $\theta = \frac{4222}{8066}$ $\theta = 121° \, 34'$; cos. $\phi = \frac{8065}{8066}$ $\phi = 179° \, 6'$; cos. $\psi = \frac{8064}{8066}$ $\psi = 178° \, 43'$. Inclination of normals 58° 26′, 0° 54′, and 1° 17′.

Faces parallel to this form occur in crystals of Garnet.

The form 1, $\frac{4}{3}$, 2 ; 2O$\frac{4}{3}$, Naumann; 4, 3, 2, Miller; and $b^{\frac{1}{4}}$, $b^{\frac{1}{3}}$, $b^{\frac{1}{2}}$, Brooke and Levy, Octahedral axes $\frac{4}{3}$ and rhombic $\frac{4}{7}$.

Cos. $\theta = \frac{28}{29}$, $\theta = 164° \, 55'$; cos. $\phi = \frac{28}{29}$, $\phi = 164° \, 55'$; cos. $\psi = \frac{21}{29}$, $\psi = 136° \, 24'$ Inclination of normals, 15° 5′, 15° 5′, and 43° 36′.

Faces parallel to this form occur in crystals of Linneite.

The form 1, $\frac{15}{11}$, $\frac{15}{7}$; $\frac{15}{7}$ O $\frac{15}{11}$, Naumann; 15, 11, 7, Miller; and $b^{\frac{1}{15}}$, $b^{\frac{1}{11}}$, $b^{\frac{1}{7}}$. Brooke and Levy; octahedral axes, $\frac{15}{33}$; rhombic, $\frac{15}{26}$.

Cos. $\theta = \frac{379}{395}$, $\theta = 163° \, 38'$; cos. $\phi = \frac{379}{395}$, $\phi = 163° \, 38'$; cos. $\psi = \frac{287}{395}$, $\psi = 138$. 45′. Inclination of normals, 16° 22′, 16° 22′, and 41° 15′.

Faces parallel to this form occur in Linneite.

The form 1, $\frac{4}{3}$, 4 ; 4 O $\frac{4}{3}$, Naumann; 4, 3, 1, Miller; and b^1, $b^{\frac{1}{3}}$, $b^{\frac{1}{4}}$, Brooke and Levy. Octahedral axes, $\frac{1}{2}$; rhombic. $\frac{4}{5}$.

Cos. $\theta = \frac{22}{26}$, $\theta = 147° \, 48'$; cos. $\phi = \frac{25}{26}$. $\phi = 164° \, 3'$; cos. $\psi = \frac{24}{26}$, $\psi = 157° \, 23'$. Inclination of normals, 32° 12′, 15° 57′, and 22° 37′.

Faces parallel to this form occur in Garnet.

The form 1, $\frac{3}{2}$, 3 ; 3 O $\frac{3}{2}$, Naumann; 3, 2, 1, Miller; and b^1, $b^{\frac{1}{2}}$, $b^{\frac{1}{3}}$, Brooke and Levy. Octahedral axes $= \frac{1}{2}$; rhombic, $\frac{3}{5}$.

Cos. $\theta = \frac{13}{14}$, $\theta = 158° \, 13'$; cos. $\phi = \frac{13}{14}$, $\phi = 158° \, 13'$; cos. $\psi = \frac{12}{14}$, $\psi = 149° \, 0'$. Inclination of normals, 21° 47′, 21° 47,′ and 31° 0′.

Faces parallel to this form occur in

Amalgam.	Diamond.	Hauerite.
Cobaltine.	Fahlerz.	Magnetite.
Cuprite.	Garnet.	Pyrite.

The form 1, $\frac{5}{3}$, 5 ; 5 O $\frac{5}{3}$, Naumann; 5, 3, 1, Miller; b^1, $b^{\frac{1}{3}}$, $b^{\frac{1}{5}}$, Brooke and Levy; octahedral axes, $\frac{5}{8}$; rhombic, $\frac{5}{8}$.

Cos. $\theta = \frac{31}{35}$, $\theta = 152° \, 20'$; cos. $\phi = \frac{31}{35}$, $\phi = 152° \, 20'$; cos. $\psi = \frac{33}{35}$, $\psi = 160° \, 32'$. Inclination of normals, 27° 40′, 27° 40′, and 19° 28′.

Faces parallel to this form occur in Boracite and Pyrite.

The form 1, 2, 4; 4 O 2, Naumann; 4, 2, 1, Miller; b^1, $b^{\frac{1}{2}}$, $b^{\frac{1}{4}}$, Brooke and Levy. Octahedral axes, $\frac{4}{7}$; rhombic, $\frac{2}{3}$.

Cos. $\theta = \frac{20}{21}$, $\theta = 162° \ 15'$; cos. $\phi = \frac{17}{21}$, $\phi = 144° \ 3'$; cos. $\psi = \frac{19}{21}$, $\psi = 154° \ 47'$. Inclination of normals, 17° 45′, 35° 57′, and 25° 13′.

Faces parallel to this form occur in Fluor, Gold, and Pyrite.

The form 1, $\frac{11}{5}$, $\frac{11}{3}$; $\frac{11}{3}$ O $\frac{11}{5}$, Naumann; 11, 5, 3, Miller; $6^{\frac{1}{11}}$, $6^{\frac{1}{5}}$, $6^{\frac{1}{3}}$, Brooke and Levy. Octahedral axes, $\frac{11}{19}$; rhombic axes, $\frac{11}{16}$

Cos. $\theta = \frac{151}{155}$, $\theta = 166° \ 57'$; cos. $\phi = \frac{119}{155}$, $\phi = 140° \ 9'$; cos. $\psi = \frac{137}{155}$, $\psi = 152° \ 7'$. Inclination of normals, 13° 3′, 39° 51′, and 27° 53′.

Faces parallel to this form occur in crystals of Fluor.

The form 1, $\frac{16}{7}$, 4; 4 O $\frac{16}{7}$, Naumann; 16, 7, 4, Miller; $6^{\frac{1}{4}}$, $6^{\frac{1}{7}}$, $6^{\frac{1}{16}}$, Brooke and Levy. Octahedral axes, $\frac{16}{27}$; rhombic axes, $\frac{16}{23}$.

Cos. $\theta = \frac{312}{321}$, $\theta = 166° \ 24'$; cos. $\phi = \frac{240}{321}$, $\phi = 138° \ 23'$; cos $\psi = \frac{289}{321}$, $\psi = 154° \ 12'$. Inclination of normals, 13° 36′, 41° 37′, and 25° 48′.

Faces parallel to this form occur in crystals of Fluor.

The form 1, $\frac{7}{3}$, 7; 7 O $\frac{7}{3}$, Naumann; 7, 3, 1, Miller; b^1, $6^{\frac{1}{3}}$, $6^{\frac{1}{7}}$, Brooke and Levy. Octahedral axes, $\frac{7}{11}$; rhombic, $\frac{7}{10}$.

Cos. $\theta = \frac{55}{59}$, $\theta = 158° \ 47'$; cos. $\phi = \frac{43}{59}$, $\phi = 136° \ 47'$; cos. $\psi = \frac{57}{59}$, $\psi = 165° \ 2'$. Inclination of normals, 21° 15′, 43° 13′, and 14° 58′.

Faces parallel to this form occur in crystals of Fluor.

The form 1, 4, 8; 8 O 4, Naumann; 8, 2, 1, Miller; b^1, $b^{\frac{1}{4}}$, $b^{\frac{1}{8}}$, Brooke and Levy. Octahedral axes, $\frac{8}{11}$; rhombic axes, $\frac{4}{5}$.

Cos. $\theta = \frac{68}{69}$, $\theta = 170° \ 14'$; cos. $\phi = \frac{33}{69}$, $\phi = 118° \ 34'$; cos. $\psi = \frac{67}{69}$, $\psi = 166° \ 10'$. Inclination of normals, 9° 46′, 61° 26′, and 13° 50′.

Faces parallel to this form have been found in crystals of Galena.

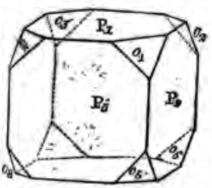


Fig. 55.

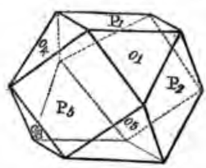


Fig. 56.

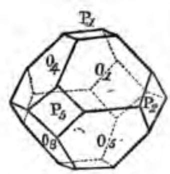


Fig. 57.

Combination of the Forms of the Cube and Octahedron.—When the faces of the cube P_1 P_2, &c., P_6 (Fig. 55), predominate, the solid angles of the cube are replaced by triangular faces o_1 o_2, &c., o_8, which are parallel to those of the inscribed octahedron. When the faces o_1 o_2, &c., o_8, are so large that the angles of their triangles meet, P_1 P_2, &c., P_6, are squares (Fig. 56). When the faces of the octahedron predominate, as in Fig. 57, the solid angles of the octahedron are replaced by square planes of the cube P_1 P_2, &c., P_6.

If θ be the angle of inclination of a face of the octahedron, as o_1, to any of the adjacent faces of the cube, as P_1 P_2, or P_5,

$$\text{Cos. } \theta = \frac{1}{\sqrt{3}} \quad \theta = 125° \ 16'.$$

Inclination of normals, o_1 and $P_1 = 54° \ 44'$.

Combination of Cube and Rhombic Dodecahedron.—When the faces of the cube P_1 P_2 P_5, &c., (Fig. 58), predominate, the faces of the rhombic dodecahedron, r_1 r_4 r_5, replace the edges of the cube.

When the faces of rhombic dodecahedron predominate (Fig. 59), the faces of the cube P_1 P_2 P_5, replace the four-faced solid angles of the rhombic dodecahedron with square planes, P_1 P_2, &c.

If θ be the angle of inclination of the face of the cube P_1 to the adjacent faces of the rhombic dodecahedron r_1 r_4, &c., and θ' the inclination of their normals,

$$\text{Cos. } \theta = \frac{1}{\sqrt{2}} \quad \theta = 135^\circ, \text{ and } \theta' = 45^\circ.$$

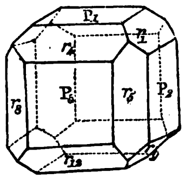


Fig. 58.

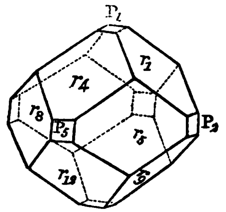


Fig. 59.

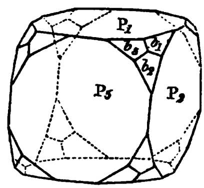


Fig. 60.

Combination of Cube and Three-faced Octahedron.—When the faces of the cube, P_1 P_2 P_5, &c. (Fig. 60), predominate, the solid angles of the cube are replaced by the three-faced solid angles of the three-faced octahedron, forming three trapezoidal planes, b_1 b_2, and b_3, for each solid angle of the cube.

When the faces of the three-faced octahedron, b_1 b_2 b_3, &c., predominate (Fig. 61), the eight-faced solid angles of the three-faced octahedron are replaced by octagonal planes of the cube P_1 P_2 P_5, &c.

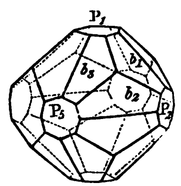


Fig. 61.

Let θ be the angle of inclination of P_1 to b_1 or b_3, θ' that of their normals, and ϕ the angle of inclination of P_1 to b_2, ϕ' that of their normals.

If $11n$ be the symbol of the three-faced octahedron,

$$\cos.\ \theta = \frac{1}{\sqrt{2 + \frac{1}{n^2}}} \quad \theta' = 180^\circ - \theta \quad \cos.\ \phi = \frac{\cos.\ \theta}{n} \quad \phi' = 180^\circ - \phi.$$

For the form 1, 1, $\frac{65}{64}$ $\cos.\ \theta = \sqrt{\frac{4225}{12546}}$ $\theta' = 125^\circ\ 28'$ $\theta' = 54^\circ\ 32'$.

$\cos.\ \phi = \sqrt{\frac{4096}{12546}}$ $\phi = 124^\circ\ 51'$ $\phi' = 55^\circ\ 9'$.

For the form 1, 1, $\frac{5}{4}$, $\cos.\ \theta = \sqrt{\frac{25}{66}}$ $\theta = 127^\circ\ 59'$ $\theta' = 52^\circ\ 1'$.

$\cos.\ \phi = \sqrt{\frac{16}{66}}$ $\phi = 119^\circ\ 29'$ $\phi' = 60^\circ\ 31'$.

For the form 1, 1, $\frac{3}{2}$, $\cos.\ \theta = \sqrt{\frac{9}{22}}$ $\theta = 129^\circ\ 46'$ $\theta' = 50^\circ\ 14'$.

$\cos.\ \phi = \sqrt{\frac{4}{22}}$ $\phi = 115^\circ\ 15'$ $\phi' = 64^\circ\ 45'$.

For the form 1, 1, $\frac{7}{4}$, $\cos.\ \theta = \sqrt{\frac{49}{114}}$ $\theta = 130^\circ\ 58'$ $\theta' = 49^\circ\ 2'$.

$\cos.\ \phi = \sqrt{\frac{16}{114}}$ $\phi = 112^\circ\ 0'$ $\phi' = 68^\circ\ 0'$.

For the form 1, 1, 2, $\cos.\ \theta = \sqrt{\frac{4}{9}}$ $\theta = 131^\circ\ 49'$ $\theta' = 48^\circ\ 11'$.

$\cos.\ \phi = \sqrt{\frac{1}{9}}$ $\phi = 109^\circ\ 29'$ $\phi' = 70^\circ\ 31'$.

For the form 1, 1, 3, cos. $\theta = \sqrt{\frac{9}{19}}$ $\theta = 133° 30'$ $\theta' = 46° 30'$.

cos. $\phi = \sqrt{\frac{1}{19}}$ $\phi = 103° 16'$ $\phi' = 76° 44'$.

For the form 1, 1, 4, cos. $\theta = \sqrt{\frac{16}{33}}$ $\theta = 134° 8'$ $\theta' = 45° 52'$.

cos. $\phi = \sqrt{\frac{1}{33}}$ $\phi = 100° 1'$ $\phi' = 79° 59'$.

Combination of Cube and Twenty-four-faced Trapezohedron.—When the faces of the cube P_1 P_2 P_5, &c., predominate (Fig. 62), the solid angles of the cube are replaced by the three-faced solid angles of the Trapezohedron forming three triangular planes a_1 a_2 a_3 for each solid angle of the cube.

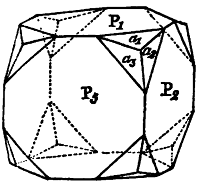


Fig. 62.

When the faces of the trapezohedron predominate (Fig. 63), the four-faced solid angles of the trapezohedron, which terminate the cubical axes, are replaced by square planes of the cube P_1 P_2 P_5, &c. Let θ be the angle of inclination of P_1 to a_1, θ' that of their normals, and ϕ the angle of inclination of P_1 to a_2 or a_3, ϕ' that of their normals.

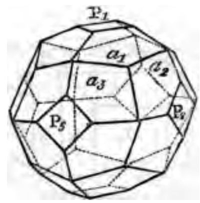


Fig. 63.

If 1 *m m* be the symbol of the twenty-four-faced trapezohedron,

$$\cos.\ \theta = \frac{1}{\sqrt{1+\frac{2}{m^2}}},\ \theta' = 180° - \theta,\ \phi = \frac{\cos.\ \theta}{m},\ \phi' = 180° - \phi.$$

For the form 1, $\frac{4}{3}$, $\frac{4}{3}$, cos. $\theta = \sqrt{\frac{16}{34}}$ $\theta = 133° 19'$ $\theta' = 46° 41'$.

cos. $\phi = \sqrt{\frac{9}{34}}$ $\phi = 120° 58'$ $\phi' = 59° 2'$.

For the form 1, $\frac{3}{2}$, $\frac{3}{2}$, cos. $\theta = \sqrt{\frac{9}{17}}$ $\theta = 136° 41'$ $\theta' = 43° 19'$.

cos. $\phi = \sqrt{\frac{4}{17}}$ $\phi = 119° 1'$ $\phi' = 60° 59'$.

For the form 1, 2, 2, cos. $\theta = \sqrt{\frac{2}{3}}$ $\theta = 144° 44'$ $\theta' = 35° 16'$.

cos. $\phi = \sqrt{\frac{1}{6}}$ $\phi = 114° 6'$ $\phi' = 65° 54'$.

For the form 1, $\frac{9}{4}$, $\frac{9}{4}$, cos. $\theta = \sqrt{\frac{81}{113}}$ $\theta = 147° 51'$ $\theta' = 32° 9'$.

cos. $\phi = \sqrt{\frac{16}{113}}$ $\phi = 112° 6'$ $\phi' = 67° 54'$.

For the form 1, $\frac{8}{3}$, $\frac{8}{3}$, cos. $\theta = \sqrt{\frac{64}{82}}$ $\theta = 152° 4'$ $\theta' = 27° 56'$.

cos. $\phi = \sqrt{\frac{9}{82}}$ $\phi = 109° 21'$ $\phi' = 70° 39'$.

For the form 1, 3, 3, cos. $\theta = \sqrt{\frac{9}{11}}$ $\theta = 154° 46'$ $\theta' = 25° 14'$.

cos. $\phi = \sqrt{\frac{1}{11}}$ $\phi = 107° 33'$ $\phi' = 72° 27'$.

For the form 1, 4, 4, cos. $\theta = \sqrt{\frac{16}{18}}$ $\theta = 160° 32'$ $\theta' = 19° 28'$.

cos. $\phi = \sqrt{\frac{1}{18}}$ $\phi = 103° 38'$ $\phi' = 76° 22'$.

For the form 1, 10, 10, cos. $\theta = \sqrt{\frac{100}{102}}$ $\theta = 171° 57'$ $\theta' = 8° 3'$.

cos. $\phi = \sqrt{\frac{1}{102}}$ $\phi = 95° 41'$ $\phi' = 84° 19'$.

For the form 1, 12, 12, cos. $\theta = \sqrt{\frac{144}{146}}$ $\theta = 173^\circ\ 17'$ $\theta' = 6^\circ\ 43'$.

cos. $\phi = \sqrt{\frac{1}{146}}$ $\phi = 99^\circ\ 45'$ $\phi' = 85^\circ\ 15'$.

For the form 1, 16, 16, cos. $\theta = \sqrt{\frac{256}{258}}$ $\theta = 174^\circ\ 57'$ $\theta' = 5^\circ\ 3'$.

cos. $\phi = \sqrt{\frac{1}{258}}$ $\phi = 93^\circ\ 34'$ $\phi' = 86^\circ\ 26'$.

For the form 1, 40, 40, cos. $\theta = \sqrt{\frac{800}{801}}$ $\theta = 177^\circ\ 8'$ $\theta' = 2^\circ\ 52'$.

cos. $\phi = \sqrt{\frac{1}{1602}}$ $\phi = 91^\circ\ 26'$ $\phi' = 88^\circ\ 34'$.

Combination of Cube and Four-faced Cube.—When the faces of the cube $P_1\ P_2\ P_5$, &c. (Fig. 64) predominate, each edge of the cube is replaced or bevelled by two faces of the four-faced cube $c_1\ c_2$, $c_3\ c_4$, $c_5\ c_6$, &c.

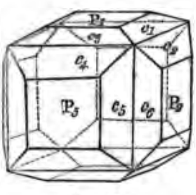


Fig. 64.

When the faces of the four-faced cube $c_1\ c_2\ c_3$, &c. (Fig. 65) predominate, every four-faced solid angle of the four-faced cube is replaced by a square plane, $P_1\ P_2$, &c., of the cube.

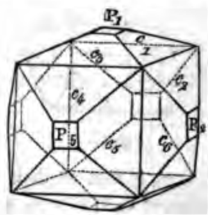


Fig. 65.

If 1, m, ∞ be the symbol of the four-faced cube,

θ the angle of inclination of P_1 to c_1 or c_3, θ' that of their normals.

ϕ the angle of inclination of P_1 to c_2 or c_4, ϕ' that of their normals.

$$\text{Then cos. } \theta = \frac{1}{\sqrt{1+\frac{1}{m^2}}} \text{ or cot. } \theta = m,\ \theta' = 180 - \theta,\ \text{cos. } \phi = \frac{\text{cos. } \theta}{m},$$

$$\text{and } \phi' = 180^\circ - \phi.$$

The inclination of P_1 to c_5 or c_6 is 90° in every case.

For the form 1, $\frac{5}{4}$, ∞, cos. $\theta = \sqrt{\frac{25}{41}}$ cot. $\theta = \frac{5}{4}$ $\theta = 141^\circ\ 20'$ $\theta' = 36^\circ\ 40'$.

cos. $\phi = \sqrt{\frac{16}{41}}$ $\phi = 128^\circ\ 40'$ $\phi' = 51^\circ\ 20'$.

For the form 1, $\frac{4}{3}$, ∞, cos. $\theta = \sqrt{\frac{16}{25}}$ cot. $\theta = \frac{4}{3}$ $\theta = 143^\circ\ 8'$ $\theta' = 36^\circ\ 52'$.

cos. $\phi = \sqrt{\frac{9}{25}}$ $\phi = 126^\circ\ 52'$ $\phi' = 53^\circ\ 8'$.

For the form 1, $\frac{3}{2}$, ∞, cos. $\theta = \sqrt{\frac{9}{13}}$ cot. $\theta = \frac{3}{2}$, $\theta = 146^\circ\ 19'$ $\theta' = 33^\circ\ 41'$.

cos. $\phi = \sqrt{\frac{4}{13}}$ $\phi = 123^\circ\ 41'$ $\phi' = 56^\circ\ 19'$.

For the form 1, 2, ∞, cos. $\theta = \sqrt{\frac{4}{5}}$ cot. $\theta = 2$ $\theta = 153^\circ\ 26'$ $\theta' = 26^\circ\ 34'$.

cos. $\phi = \sqrt{\frac{1}{5}}$ $\phi = 116^\circ\ 34'$ $\phi' = 63^\circ\ 26'$.

For the form 1, $\frac{5}{2}$, ∞, cos. $\theta = \sqrt{\frac{25}{29}}$ cot. $\theta = \frac{5}{2}$ $\theta = 158^\circ\ 12'$ $\theta' = 21^\circ\ 48'$.

cos. $\phi = \sqrt{\frac{4}{29}}$ $\phi = 111^\circ\ 48'$ $\phi' = 68^\circ\ 12'$.

For the form 1, 3, ∞, cos. $\theta = \sqrt{\frac{9}{10}}$ cot. $\theta = 3$ $\theta = 161^\circ\ 34'$ $\theta' = 18^\circ\ 26'$.

cos. $\phi = \sqrt{\frac{1}{10}}$ $\phi = 108^\circ\ 26'$ $\phi' = 71^\circ\ 34'$.

For the form 1, 4, ∞, cos. $\theta = \sqrt{\frac{16}{17}}$ cot. $\theta = 4$ $\theta = 165^\circ\ 58'$ $\theta' = 14^\circ\ 2'$.

cos. $\phi = \sqrt{\frac{1}{17}}$ $\phi = 104^\circ\ 2'$ $\phi' = 75^\circ\ 58'$.

For the form 1, 5, ∞, cos. $\theta = \sqrt{\frac{25}{26}}$ cot. $\theta = 5$ $\theta = 168^\circ\ 41'$ $\theta' = 11^\circ\ 19'$.

cos. $\phi = \sqrt{\frac{1}{26}}$ $\phi = 101^\circ\ 19'$ $\phi' = 78^\circ\ 41'$.

Combination of Cube and Six-faced Octahedron.—When the faces of the cube P_1 P_2 P_6, &c. (Fig. 66), predominate, each solid angle of the cube is replaced by a six-faced solid angle of the six-faced octahedron, forming six triangular planes e_1 e_2 e_3 e_4 e_5 e_6 for each solid angle of the cube.

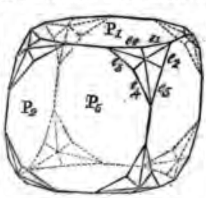


Fig. 66.

When the faces of six-faced octahedron e_1 e_2 e_3, &c. (Fig. 67), predominate, the eight-faced solid angles of the six-faced octahedron are replaced by octagonal planes P_1 P_2, &c., of the cube.

Fig. 67.

If 1, m, n be the symbol of the six-faced octahedron, θ the angle of inclination of P_1 to e_1, or e_6, θ' that of their normals.

ϕ the angle of inclination of P_1 to e_2, or e_5, ϕ' that of their normals.

ψ the angle of inclination of P_1 to e_3, or e_4, ψ' that of their normals.

Cos. $\theta = \dfrac{1}{\sqrt{1+\frac{1}{m^2}+\frac{1}{n^2}}}$ $\theta' = 180° - \theta$ cos. $\phi = \dfrac{\cos.\ \theta}{m}$ $\phi' = 180° - \phi$; cos. $\psi = \dfrac{\cos.\ \theta}{n}$ $\psi' = 180° - \psi'$.

For the form 1, $\frac{4}{4}$, $\frac{4}{3}$, $\theta = 135°\ 0'$, $\theta = 45°\ 0'$; $\phi = 124°\ 27'$, $\phi' = 55°\ 33'$; $\psi = 115°\ 16'$, $\psi' = 64°\ 54'$.

For the form 1, $\frac{64}{63}$, 64, $\theta = 135°\ 37'$, $\theta' = 44°\ 33'$; $\phi = 134°\ 33'$, $\phi' = 45°\ 27'$; $\psi = 90°\ 38'$, $\psi' = 89°\ 22'$.

For the form 1, $\frac{4}{3}$, 2, $\theta = 137°\ 58'$, $\theta' = 42°\ 2'$; $\phi = 123°\ 51'$, $\phi' = 56°\ 9'$; $\psi = 111°\ 48'$, ψ' $68°\ 12'$.

For the form 1, $\frac{14}{11}$ $\frac{14}{7}$, $\theta = 139°\ 0'$, $\theta' = 41°\ 0'$; $\phi = 123°\ 36'$, $\phi' = 56°\ 24'$ $\psi = 110°\ 37'$, $\psi' = 69°\ 23'$.

For the form 1, $\frac{4}{3}$, 4, $\theta = 141°\ 40'$, $\theta' = 38°\ 20'$; $\phi = 126°\ 2'$, $\phi' = 53°\ 58'$ $\psi = 101°\ 19'$, $\psi' = 78°\ 41'$.

For the form 1, $\frac{3}{2}$, 3, $\theta = 143°\ 18'$, $\theta' = 36°\ 42'$; $\phi = 122°\ 19'$, $\phi' = 57°\ 41'$; $\psi = 105°\ 30'$, $\psi' = 74°\ 30'$.

For the form 1, $\frac{4}{3}$, 5, $\theta = 147°\ 41'$, $\theta' = 32°\ 19'$; $\phi = 120°\ 28'$, $\phi' = 59°\ 32'$; $\psi = 99°\ 4'$, $\psi' = 80°\ 16'$.

For the form 1, 2, 4, $\theta = 150°\ 48'$, $\theta' = 29°\ 12'$; $\phi = 115°\ 53'$, $\phi = 64°\ 7'$; $\psi = 102°\ 36'$, $\psi' = 77°\ 24'$.

For the form 1, $\frac{11}{5}$, $\frac{11}{3}$, $\theta = 152°\ 4'$, $\theta' = 27°\ 56'$; $\phi = 113°\ 41'$, $\phi' = 66°\ 19'$; $\psi = 103°\ 57'$, $\psi' = 76°\ 3'$.

For the form 1, $\frac{16}{7}$, 4, $\theta = 153°\ 15'$, $\theta' = 26°\ 45'$; $\phi = 113°\ 0'$, $\phi' = 67°\ 0'$; $\psi = 102°\ 54'$, $\psi' = 77°\ 6'$.

For the form 1, $\frac{7}{3}$, 7, $\theta = 155°\ 41'$, $\theta' = 24°\ 19'$; $\phi = 112°\ 59'$, $\phi' = 67°\ 1'$ $\psi = 97°\ 29'$, $\psi' = 82°\ 31'$.

For the form 1, 4, 8, $\theta = 164°\ 23'$, $\theta' = 15°\ 37'$; $\phi = 103°\ 56'$, $\phi' = 76°\ 4'$ $\psi = 96°\ 55'$, $\psi' = 83°\ 5'$.

Combination of Octahedron and Rhombic Dodecahedron.—When the faces of the octahedron predominate, as o_1 o_4 o_8, &c. (Fig. 68), the planes of the rhombic dodecahedron r_1 r_5 r_4, &c., replace or truncate the edges of the octahedron.

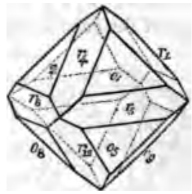


Fig. 68.

When the faces of the rhombic dodecahedron predominate, as $r_1 r_4 r_5$, &c. (Fig. 69), the three-faced solid angles of the rhombic dodecahedron are replaced by triangular planes o_1 o_4 o_8, &c. of the octahedron.

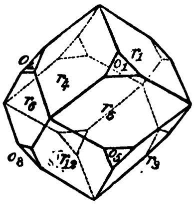


Fig. 69

The inclination of o_1 to any of the adjacent faces r_1, r_4, or r_5, is 144° 44′, that of their normals 35° 16′.

Combination of the Octahedron and Three-faced Octahedron.—When the faces of the octahedron o_1 o_4 o_5 o, &c. (Fig. 70), predominate, the edges of the octahedron are replaced or bevelled by two planes of the three-faced octahedron.

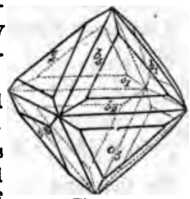


Fig. 70.

When the faces of the three-faced octahedron b_1 b_2 b_3, &c. (Fig. 71), predominate, the three-faced solid angles of the three-faced octahedron are replaced by triangular planes o_1, o_4, o_5, o_8, &c., of the octahedron.

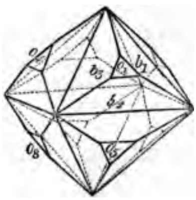


Fig. 71.

If $11n$ be the symbol of the three-faced octahedron, θ the angle of inclination of o_1 to b_1, b_2, or b_3, θ' that of their normals,

$$\text{Then } \cos.\theta = \frac{2 + \frac{1}{n}}{\sqrt{3\left(2 + \frac{1}{n^2}\right)}} \text{ and } \theta' = 180^\circ - \theta.$$

For the form 1, 1, $\frac{65}{64}$ $\theta = 179°\ 35'$ $\theta' = 0°\ 25'$.

For the form 1, 1, $\frac{5}{4}$ $\theta = 174°\ 14'$ $\theta' = 5°\ 46'$.

For the form 1, 1, $\frac{3}{2}$ $\theta = 169°\ 57'$ $\theta' = 10°\ 3'$.

For the form 1, 1, $\frac{7}{4}$ $\theta = 166°\ 44'$ $\theta' = 13°\ 16'$.

For the form 1, 1, 2 $\theta = 164°\ 12'$ $\theta' = 15°\ 58'$.

For the form 1, 1, 3 $\theta = 158°\ 0'$ $\theta' = 22°\ 0'$.

For the form 1, 1, 4 $\theta = 154°\ 46'$ $\theta' = 25°\ 14'$.

Combination of the Octahedron and Twenty-four Faced Trapezohedron.—When the faces of the octahedron o_1 o_4 o_5 o_8 (Fig. 72) predominate, the solid angles of the octahedron are replaced by the four-faced solid angles of the trapezohedron, which terminate its cubical axes.

When the faces a_1 a_2 a_3, &c. (Fig. 73), of the trapezohedron predominate, the three-faced solid angles of the trapezohedron are replaced by triangular planes o_1, o_4, o_5, o_8, of the octahedron.

Fig. 72.

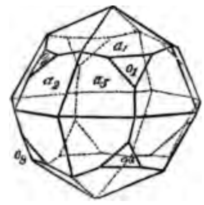


Fig. 73.

If 1, m, m be the symbol of the twenty-four-faced trapezohedron, θ the angle of inclination of the face o_1 to a_1, a_2, or a_3; θ' that of their normals.

$$\text{Cos. } \theta = \frac{1 + \frac{2}{m}}{\sqrt{3\left(1 + \frac{2}{m^2}\right)}} \qquad \theta' = 180^\circ - \theta.$$

For the form 1, $\frac{4}{3}$, $\frac{4}{3}$	$\theta = 171^\circ\ 57'$	$\theta' = 8^\circ\ 3'$.
For the form 1, $\frac{3}{2}$, $\frac{3}{2}$	$\theta = 168^\circ\ 35'$	$\theta' = 11^\circ\ 25'$.
For the form 1, 2, 2	$\theta = 160^\circ\ 32'$	$\theta' = 19^\circ\ 28'$.
For the form 1, $\frac{9}{4}$, $\frac{9}{4}$	$\theta = 157^\circ\ 25'$	$\theta' = 22^\circ\ 35'$.
For the form 1, $\frac{8}{3}$, $\frac{8}{3}$	$\theta = 153^\circ\ 12'$	$\theta' = 26^\circ\ 48'$.
For the form 1, 3, 3	$\theta = 150^\circ\ 30'$	$\theta' = 29^\circ\ 30'$.
For the form 1, 4, 4	$\theta = 144^\circ\ 44'$	$\theta' = 35^\circ\ 16'$.
For the form 1, 10, 10	$\theta = 133^\circ\ 19'$	$\theta' = 46^\circ\ 41'$.
For the form 1, 12, 12	$\theta = 131^\circ\ 59'$	$\theta' = 48^\circ\ 1'$.
For the form 1, 16, 16	$\theta = 130^\circ\ 19'$	$\theta' = 49^\circ\ 41'$.
For the form 1, 40, 40	$\theta = 127^\circ\ 17'$	$\theta' = 52^\circ\ 43'$.

Combination of the Octahedron and Four-faced Cube.—When the faces of the octahedron, o_1 o_4 o_5 o_8 (Fig. 74), predominate, the solid angles of the octahedron are replaced by the four-faced solid angles of the four-faced cube c_1 c_3, &c.

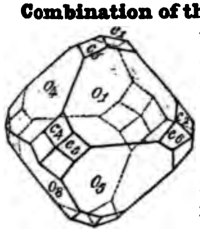


Fig. 74.

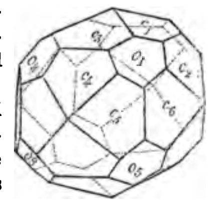


Fig. 75.

When the faces of the four-faced cube c_1 c_2 c_3, &c. (Fig. 75), predominate, the six-faced solid angles of the four-faced cube are replaced by planes of the octahedron o_1, o_4, o_5, o_8, &c.

If θ be the angle of inclination of the face o_1 of the octahedron, to any of the faces c_1 c_2 c_3 c_4 c_5 c_6 of the four-faced cube whose symbol is 1 m ∞, θ' that of their normals.

$$\text{Cos. } \theta = \frac{1 + \frac{1}{m}}{\sqrt{3\left(1 + \frac{1}{m^2}\right)}} \qquad \theta' = 180^\circ - \theta.$$

For the form 1, $\frac{5}{4}$, ∞	$\theta = 144^\circ\ 15'$	$\theta' = 35^\circ\ 45'$.
For the form 1, $\frac{4}{3}$, ∞	$\theta = 143^\circ\ 56'$	$\theta' = 36^\circ\ 49'$.
For the form 1, $\frac{3}{2}$, ∞	$\theta = 143^\circ\ 11'$	$\theta' = 36^\circ\ 49'$.
For the form 1, 2, ∞	$\theta = 141^\circ\ 46'$	$\theta' = 39^\circ\ 14'$.
For the form 1, $\frac{5}{2}$, ∞	$\theta = 139^\circ\ 38'$	$\theta' = 41^\circ\ 22'$.

For the form 1, 3, ∞ $\theta = 136° 55'$ $\theta' = 43° 5'$.
For the form 1, 4, ∞ $\theta = 134° 26'$ $\theta' = 45° 34'$.
For the form 1, 5, ∞ $\theta = 132° 48'$ $\theta' = 47° 12'$.

Combination of the Octahedron and Six-faced Octahedron.—When the faces $o_1\ o_4\ o_5\ o_8$ (Fig. 76), of the octahedron predominate, the solid angles of the octahedron are replaced by the eight-faced solid angles of the six-faced octahedron.

Fig. 76.

When the faces $e_1\ e_2\ e_3\ e_4$, &c. (Fig. 77), of the six-faced octahedron predominate, each six-faced solid angle of the six-faced octahedron is replaced by a plane, $o_1\ o_4\ o_5$, &c. of the octahedron.

Fig. 77.

If 1, m, n be the symbol of the six-faced octahedron, θ the angle of inclination of a face of the octahedron o_1 to any of the six adjacent faces $e_1\ e_2\ e_3\ e_4\ e_5$ or e_6 of the six-faced octahedron, θ' that of their normals,

$$\text{Cos. } \theta = \frac{1 + \frac{1}{m} + \frac{1}{n}}{\sqrt{3\left(1 + \frac{1}{m^2} + \frac{1}{n^2}\right)}} \qquad \theta' = 180° - \theta.$$

For the form 1, $\frac{5}{4}$, $\frac{5}{3}$ $\theta = 168° 28'$ $\theta' = 11° 32'$.
For the form 1, $\frac{64}{63}$, 64 $\theta = 145° 22'$ $\theta' = 34° 38'$.
For the form 1, $\frac{4}{3}$, 2 $\theta = 164° 47'$ $\theta' = 15° 13'$.
For the form 1, $\frac{15}{11}$, $\frac{15}{7}$ $\theta = 163° 28'$ $\theta' = 16° 32'$.
For the form 1, $\frac{4}{3}$, 4 $\theta = 154° 56'$ $\theta' = 25° 4'$.
For the form 1, $\frac{3}{2}$, 3 $\theta = 157° 47'$ $\theta' = 22° 13'$.
For the form 1, $\frac{5}{3}$, 5 $\theta = 151° 26'$ $\theta' = 28° 34'$.
For the form 1, 2, 4 $\theta = 151° 52'$ $\theta' = 28° 8'$.
For the form 1, $\frac{11}{5}$, $\frac{11}{3}$ $\theta = 151° 47'$ $\theta' = 28° 13'$.
For the form 1, $\frac{16}{7}$, 4 $\theta = 150° 28'$ $\theta' = 29° 32'$.
For the form 1, $\frac{7}{3}$, 7 $\theta = 145° 46'$ $\theta' = 34° 14'$.
For the form 1, 4, 8 $\theta = 139° 52'$ $\theta' = 40° 8'$.

Combination of the Rhombic Dodecahedron and Three-faced Octahedron.—When the faces of the rhombic dodecahedron $r_1\ r_4\ r_5$ &c. (Fig. 78), predominate, a three-faced solid angle of the three-faced octahedron replaces each three-faced solid angle of the rhombic dodecahedron.

Fig. 78.

When the faces of three-faced octahedron $b_1\ b_2\ b_3$, &c. (Fig. 79), predominate, each edge of the three-faced octahedron, which joins its eight-faced solid angles, is replaced by a plane of the rhombic dodecahedron.

Fig. 79.

If 1 1 n be the symbol of the three-faced octahedron, θ the angle of inclination of b_1 to r_1, or b_3 to r_4, θ' that of their normals,

$$\text{Cos. } \theta = \frac{2}{\sqrt{2\left(2 + \frac{1}{n^2}\right)}} \qquad \theta' = 180^\circ - \theta.$$

For the form 1, 1, $\frac{65}{64}$ $\theta = 145^\circ\ 9'$ $\theta' = 34^\circ\ 51'$.
For the form 1, 1, $\frac{5}{4}$ $\theta = 150^\circ\ 30'$ $\theta' = 29^\circ\ 30'$.
For the form 1, 1, $\frac{3}{2}$ $\theta = 154^\circ\ 46'$ $\theta' = 25^\circ\ 14'$.
For the form 1, 1, $\frac{7}{4}$ $\theta = 158^\circ\ 0'$ $\theta' = 22^\circ\ 0'$.
For the form 1, 1, 2 $\theta = 160^\circ\ 32'$ $\theta' = 19^\circ\ 28'$.
For the form 1, 1, 3 $\theta = 166^\circ\ 44'$ $\theta' = 13^\circ\ 16'$.
For the form 1, 1, 4 $\theta = 169^\circ\ 58'$ $\theta' = 10^\circ\ 2'$.

Combination of the Rhombic Dodecahedron and Twenty-four-Faced apezohedron.—For the trapezohedron, whose symbol is 1, 2, 2,

When the faces of the rhombic dodecahedron $r_1\ r_4\ r_5$, &c. (Fig. 80), predominate, the edges of the rhombic dodecahedron are replaced by planes $a_1\ a_2\ a_3$, &c. of the trapezohedron.

Fig. 80.

When the faces of the same form of the trapezohedron $a_1\ a_2\ a_3$, &c. (Fig. 81), predominate, each four-faced solid angle of the trapezohedron, which terminates its rhombic axis, is replaced by a plane of the rhombic dodecahedron $r_1\ r_4\ r_5$, &c.

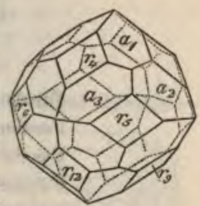


Fig. 81.

If 1 m m be the symbol of the pezohedron, when m is greater than 2, the four-faced solid gles of the rhombic dodecahedron are replaced by the four-ed solid angles of the trapezohedron, which terminate its cubical axes. When m is s than 2, the three-faced solid angles of the rhombic dodecahedron are replaced by the ee-faced solid angles of the trapezohedron.

If 1 m m be the symbol of the twenty-four-faced trapezohedron, θ the inclination of to r_1 or r_4, of a_2 to r_1 or r_5, &c., θ' that of their normals,

$$\text{Cos. } \theta = \frac{1 + \frac{1}{m}}{\sqrt{2\left(1 + \frac{2}{m^2}\right)}} \qquad \theta' = 180^\circ - \theta.$$

For the form 1, $\frac{4}{3}$, $\frac{4}{3}$ $\theta = 148^\circ\ 5'$ $\theta' = 31^\circ\ 55'$.
For the form 1, $\frac{3}{2}$, $\frac{3}{2}$ $\theta = 149^\circ\ 2'$ $\theta' = 30^\circ\ 58'$.
For the form 1, 2, 2 $\theta = 150^\circ\ 0'$ $\theta' = 30^\circ\ 0'$.
For the form 1, $\frac{9}{4}$, $\frac{9}{4}$ $\theta = 149^\circ\ 51'$ $\theta' = 30^\circ\ 9'$.
For the form 1, $\frac{8}{3}$, $\frac{8}{3}$ $\theta = 149^\circ\ 12'$ $\theta' = 30^\circ\ 48'$.
For the form 1, 3, 3 $\theta = 148^\circ\ 31'$ $\theta' = 31^\circ\ 29'$.
For the form 1, 4, 4 $\theta = 146^\circ\ 27'$ $\theta' = 33^\circ\ 33'$.
For the form 1, 10, 10 $\theta = 140^\circ\ 22'$ $\theta' = 39^\circ\ 38'$.
For the form 1, 12, 12 $\theta = 139^\circ\ 32'$ $\theta' = 40^\circ\ 28'$.
For the form 1, 16, 16 $\theta = 138^\circ\ 27'$ $\theta' = 41^\circ\ 33'$.
For the form 1, 40, 40 $\theta = 136^\circ\ 25'$ $\theta' = 43^\circ\ 35'$.

Combination of the Rhombic Dodecahedron and Four-faced Cube.—When the faces $r_1\ r_4\ r_5$, &c. (Fig. 82), of the rhombic dodecahedron predominate, each four-faced solid angle of the rhombic dodecahedron is replaced by a four-faced solid angle of the four-faced cube.

Fig. 82.

When the faces of the four-faced cube $e_1\ e_3\ e_4\ e_5$, &c. (Fig. 83), predominate, the edges of the four-faced cube which join its three-faced solid angles are replaced by planes of the rhombic dodecahedron $r_1\ r_4\ r_5$, &c.

Fig. 83.

If 1, m, ∞ be the symbol of the four-faced cube, θ the inclination of e_3 or e_4 to r_4, or of e_1 or e_2 to r_1, &c., θ' that of their normals,

$$\text{Cos. } \theta = \frac{1 + \frac{1}{m}}{\sqrt{2\left(1 + \frac{1}{m^2}\right)}} \quad \theta' = 180^\circ - \theta.$$

For the form 1, $\frac{5}{4}$, ∞	$\theta = 173^\circ\ 40'$	$\theta' = 6^\circ\ 20'$.
For the form 1, $\frac{4}{3}$, ∞	$\theta = 171^\circ\ 52'$	$\theta' = 8^\circ\ 8'$.
For the form 1, $\frac{3}{2}$, ∞	$\theta = 168^\circ\ 41'$	$\theta' = 11^\circ\ 19'$.
For the form 1, 2, ∞	$\theta = 161^\circ\ 34'$	$\theta' = 18^\circ\ 26'$.
For the form 1, $\frac{5}{2}$, ∞	$\theta = 156^\circ\ 48'$	$\theta' = 23^\circ\ 12'$.
For the form 1, 3, ∞	$\theta = 153^\circ\ 26'$	$\theta' = 26^\circ\ 34'$.
For the form 1, 4, ∞	$\theta = 149^\circ\ 2'$	$\theta' = 30^\circ\ 58'$.
For the form 1, 5, ∞	$\theta = 146^\circ\ 19'$	$\theta' = 33^\circ\ 41'$.

Combination of the Rhombic Dodecahedron and Six-faced Octahedron.—When the symbol of the six-faced octahedron is 1, m, n, and the form such that $mn = m + n$. If the faces of the rhombic dodecahedron $r_1\ r_4\ r_5$, &c. (Fig. 84), predominate, the edges of the rhombic dodecahedron are replaced or bevelled by two planes of the six-faced octahedron.

Fig. 84.

When the faces $e_1\ e_2\ e_4$, &c., of the six-faced octahedron (Fig. 85), predominate, each four-faced solid angle of the six-faced octahedron is replaced by a plane of the rhombic dodecahedron.

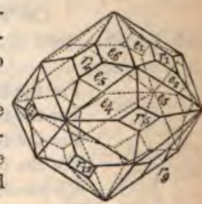


Fig. 85.

When mn is greater than $m + n$, the four-faced solid angles of the rhombic dodecahedron are replaced by the eight-faced solid angles of the octahedron.

When $m\,n$ is less than $m + n$, the three-faced solid angles of the rhombic dodecahedron are replaced by the six-faced solid angles of the six-faced octahedron.

If 1, m, n be the symbol of the six-faced octahedron, θ the inclination of r_1 to e_1 or e_2, or of r_4 to e_5 or e_6, &c., θ' that of their normals,

$$\cos.\ \theta = \frac{1 + \frac{1}{m}}{\sqrt{2\left(1 + \frac{1}{m^2} + \frac{1}{n^2}\right)}} \qquad \theta' = 180 - \theta.$$

For the form 1, $\frac{5}{4}$, $\frac{5}{3}$	$\theta = 153° 56'$	$\theta' = 26° 4'$.
For the form 1, $\frac{64}{63}$, 64	$\theta = 179° 13'$	$\theta' = 0° 47'$.
For the form 1, $\frac{4}{3}$, 2	$\theta = 156° 48'$	$\theta' = 23° 12'$.
For the form 1, $\frac{15}{11}$, $\frac{15}{7}$	$\theta = 157° 40'$	$\theta' = 22° 20'$.
For the form 1, $\frac{4}{3}$, 4	$\theta = 166° 6'$	$\theta' = 13° 54'$.
For the form 1, $\frac{3}{2}$, 3	$\theta = 160° 54'$	$\theta' = 19° 6'$.
For the form 1, $\frac{5}{3}$, 5	$\theta = 162° 59'$	$\theta' = 17° 1'$.
For the form 1, 2, 4	$\theta = 157° 47'$	$\theta' = 22° 13'$.
For the form 1, $\frac{11}{5}$, $\frac{11}{3}$	$\theta = 155° 20'$	$\theta' = 24° 40'$.
For the form 1, $\frac{16}{7}$, 4	$\theta = 155° 12'$	$\theta' = 24° 48'$.
For the form 1, $\frac{7}{3}$, 7	$\theta = 157° 1'$	$\theta' = 22° 59'$.
For the form 1, 4, 8	$\theta = 148° 21'$	$\theta' = 31° 39'$.

Complicated Combinations of the Forms of the Cubical System.—Instances of more complicated combinations of the forms of the cubical system than those already given frequently occur; but a diligent study of the simple ones, already given, will enable us to determine readily to what form each face of the crystal should be referred. The determination of the forms to which the faces of a crystal are parallel, is technically termed "reading a crystal;" the particular species to which each form belongs is generally found by measurement of the angles with a goniometer. Many species, however, may be recognised by observing the parallelism of the edges of the faces to one another, according to what is called the *zone theory*. This will be described hereafter.

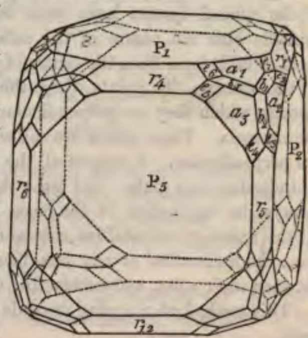


Fig. 86.

We have already given an instance of a complicated combination of forms in a crystal of Fluor spar.

The simple combinations of forms already given enable us to read this crystal with ease, and show that the faces P_1, P_2, P_5, &c., are faces of the cube; r_1 r_2, &c., r_{12}, those of the rhombic dodecahedron; a_1 a_2 and a_3, are faces of the twenty-four-faced trapezohedron; b_1 b_2 and b_3 of a three-faced cube; and e_1 e_2 e_3, &c., e_6 the faces of a six-faced octahedron.

It requires, however, actual measurement of the inclination of the faces to determine the particular species of the last three forms.

In some works on Mineralogy, as, for instance, the early editions of Phillips's "Mineralogy," the inclinations only of such faces are given without any reference to their symbols; in other works, such as the elaborate description of Mr. Turner's collection, by Levy, from which Fig. 86 is taken, the faces are indicated only by their symbols, and the angles are not given.

The tables annexed to the previously described simple combinations will afford the student a ready means of recognising the species of the forms from the angular measurements given by Phillips; or of supplying those measurements to the crystals described by Levy.

The faces a_1 a_2 a_3, are marked a^3 in Levy's figure; hence, they are faces of a twenty-four-faced trapezohedron, whose symbol is 133 (see symbols of this figure, p. 305).

The faces b_1 b_2 b_3 are marked $a^{\frac{1}{2}}$ in Levy; they are faces of a three-faced octahedron, whose symbol is 112. The faces e_1 e_2 e_3 e_4 e_5 e_6 are marked $i = b^1\, b^{\frac{1}{2}}\, b^{\frac{1}{3}}$, and are faces of a six-faced octahedron, whose symbol is 1, 2, 4 (see p. 315).

The inclination of the face P_5 to any of the faces r_4 r_5 r_6 or r_{12}, is 135° (p. 316).

The inclination of P_5 to a_3 is 154° 46′, and of P_5 to a_1 or a_2, 107° 33′ (p. 317).

The inclination P_5 to b_2 or b_3 is 131° 49′, and of P_5 to b_1, is 109° 29′ (p. 316).

The inclination of P_5 to e_4 or e_5 is 150° 48′, to e_3 or e_6 is 115° 53′, and to e_1 or e_2, 102° 36′ (p. 319).

The inclination of r_4 to e_5 or e_6, or of r_5 to e_4 or e_3, is 157° 47′ (p. 325).

The above is sufficient to show how the inclinations of the faces of a crystal to each other may be determined from a knowledge of their symbols.

Sphere of Projection.—If we suppose the cube in which each of the forms of the cubical system have been inscribed, placed in a sphere, whose centre shall coincide with the centre of the cube; then, if lines be drawn perpendicular to the faces of each form from the centre of the sphere, and produced till they cut the surface of the sphere; the points where they cut the sphere will serve as indications of the faces to which they are perpendicular, or to which, in mathematical language, they are the normals. These points are called the *poles* of the faces of the crystal to which they are perpendicular. A map of all the forms which we have hitherto described may thus be indicated on a globe; and since the inclination of the normals to any two planes is always the inclination of the faces, less 180°; a globe, with the poles of the faces of all the forms of a crystalline substance described on it, will enable us speedily to determine the inclination of any one face to another, by simply measuring the distance between their poles, and subtracting this from 180°.

This method of mapping crystals was invented by Professor Neumann, of Königsberg.

Zones.—In the combinations of crystals, it frequently occurs that some edges are parallel to one another; instances of this will be seen in Figs. 58, 59, 64, 65, 70, 71, and many others. The poles of the faces, whose intersections are parallel to each other, all lie in a great circle of the sphere of projection—a great circle being the intersection of a plane passing through the centre of the sphere and its surface. When three or more faces of a crystal have their poles in the same *great circle*, they are said to form a *zone*, and the *great circle* is called a *zone circle.*

Maps of Crystals.—A map may be drawn on a plane surface, representing the sphere of projection, with the poles of all the faces of a crystal. Such maps, when understood, convey to the mind a vast degree of information relative to the inclinations of the faces, which could not otherwise be represented, solve many problems in crystallography, and exhibit the position of the most important zones. Professor Miller, of Cambridge, has inserted an exceedingly valuable series of these maps of crystals in the last edition of Phillips's mineralogy. The authors of the present treatise take this opportunity of expressing their obligation to Professor Miller's work, to which they would beg to refer all those who would wish to master the science of crystallography.

The *stereographic* projection of the sphere, in which the eye of the observer is supposed to be placed on the surface of the sphere in the pole of the great circle upon which the sphere is projected, is that generally made use of for these maps. It possesses this advantage: all circles on the sphere are represented on the map by straight lines or arcs of circles.

Map of the principal Zones of the Cubical System.—With P_1 as a centre, and a radius $P_1 P_2$ of any convenient length, describe a circle $P_2 P_3 P_4 P_5$.

Through P_1 draw the diameters $P_3 P_5$ and $P_2 P_4$ perpendicular to each other.

With P_5 as a centre, and radius equal $P_5 P_2$, or $P_5 P_4$, describe the arc $P_4 r_2 P_2$, cutting $P_3 P_1$ in r_2.

With P_3, P_2 and P_4 as centres, and radii equal to the former, describe similar arcs, cutting $P_1 P_5$ in r_4, $P_1 P_4$ in r_3, and $P_1 P_2$ in r_1.

Let O_1 O_2 O_3 O_4 be the points where these arcs intersect each other.

Join $P_1 O_1$, $P_1 O_2$, $P_1 O_3$, $P_1 O_4$, and produce them to cut the circle $P_2 P_3 P_4$ in the points r_5 r_6 r_7 and r_8.

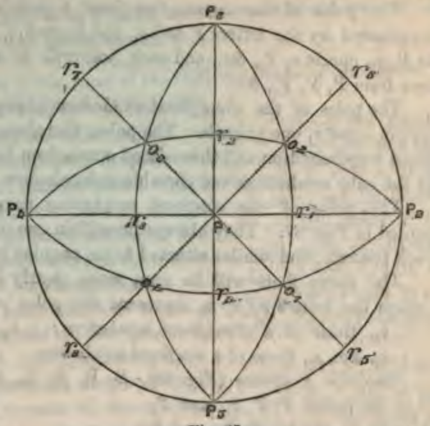


Fig. 87.

Figure 87, thus described, is an orthographic projection of the sphere, representing a hemisphere with the principal zone circles of the cubical system.

P_1, P_2, P_3, P_4, and P_5, are the poles of the faces of the cube, indicated by the same letters in the preceding figures; o_1 o_2 o_3 o_4 the poles of the octahedron; r_1 r_2 r_8 the poles of the faces of the rhombic dodecahedron. $P_1 r_1$, $r_1 P_2$, $P_2 r_5$, and the similar lines and arcs, represent arcs of great circles 45° in length.

If the north pole on a globe be chosen as the pole of P_1, the equator will represent the circle $P_2 P_3 P_4$. Let P_2 be the point where the first meridian of longitude, $P_1 P_2$, cuts the equator; then P_4 will be the point where the meridian of 180°, and P_3 and P_5, the points where the meridians of 90° east and west longitude, cut the equator.

Let r_1 r_2 r_3 r_4 be the points where the circle of latitude of 45° cuts these meridians; r_5 r_6 r_7 r_8 points in the equator equidistant from P_2 P_5, &c. Draw great circles passing through P_1 r_5, P_5 r_1, P_2 r_4 intersecting in o_1, and similar circles for the other octants of the sphere, and the map Fig. 87 will be described on the globe. If such a map be thus delineated on a black globe, or one of slate, an approximation to the angles given in the description of the faces and their combinations, in the previous part of this treatise, may be made,—particularly when the poles of other forms are marked on the globe by methods which will be presently described. The arc P_1 P_2, measured by the brazen meridian, or by the flexible brass meridian usually sold with globes, will give the inclination of two adjacent faces of the cube; the distance between r_1 and r_4, similarly measured, the inclination of the normals of two adjacent faces of the rhombic dodecahedron; o_1 o_2 that of the normals, of adjacent faces of the octahedron; P_1 o_1 of the normals of the faces of the cube to that of the octahedron, represented by those letters; r_1 o_1 of the rhombic dodecahedron to the octahedron; and so on.

The great circles represented in Fig. 87 by the lines P_2 P_4 and P_3 P_5, and by the circle P_2 P_3 P_4, are the zones in which the poles of the *four-faced cube* always lie, one pole lying in each of the arcs represented by the letters P and r, and at the same distance from P in each arc.

The poles of the *four-faced cube* lie, therefore, in the zone circle passing through the poles of the cube and rhombic dodecahedron.

The poles of the *twenty-four-faced trapezohedron* always lie in one of the arcs terminated by the letters P and o, one in each. Thus one pole will lie in P_1 o_1, one in P_2 o_1, one in o_1 P_5, &c., and each pole will be at the same angular distance in those arcs from P_1 P_2 P_5, &c.

The poles of the *three-faced octahedron* always lie in the arcs terminated by the letters o and r, one in each. The poles, therefore, of every form of the twenty-four-faced trapezohedron and three-faced octahedron lie in zones, which pass through poles of the cube octahedron and rhombic dodecahedron.

The poles of the *six-faced octahedron* never lie in any of the zones represented in Fig. 87. They always lie within one of the spherical triangles P o r, one in each triangle, and similar situated to its angular points.

The above facts will be seen more clearly by a reference to Figs. 89 and 90, in which the letters a_1 a_2 a_3 represent the poles of a *twenty-four-faced trapezohedron;* b_1 b_2 b_3, those of a *three-faced octahedron;* c_1 c_2, &c., c_6, those of a *four-faced cube;* e_1 e_2 e_3, &c., e_6, those of a *six-faced octahedron.*

Describe a square (Fig. 88), B_5 B_6 B_7 B_8, about the circle P_2 P_3 P_4, touching it in the points P_2 P_3 P_4 and P_5. Join P_3 P_5, P_2 P_4, B_6 B_8, and B_7 B_5; the last two cutting the circle in the points r_6, r_8, r_7 and r_5.

With B_8 as a centre and radius equal B_8 r_5 or B_8 r_7, describe the arc r_7 r_2 r_1 r_5, cutting P_1 P_3 in r_2, and P_1 P_2 in r_1. With B_5, B_6 and B_7 as centres, and with the same radius, describe the arcs r_8 r_3 r_6, r_7 r_3 r_5, and r_6 r_1 r_8.

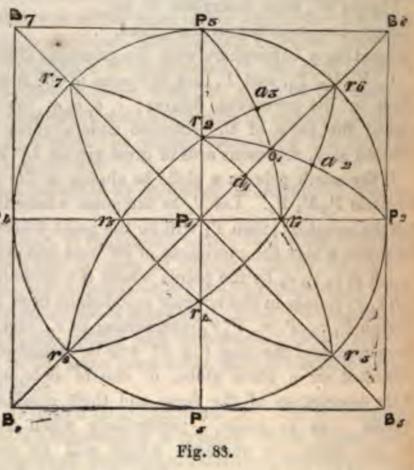


Fig. 88.

The points indicated by the letters P and r will represent the same poles as in Fig. 87. Each arc such as r_7 r_2 r_1 r_5 will represent the half of a zone circle, in which all the poles of the six-faced octahedron whose symbols are of the form $1, \frac{n}{n-1}, n$ will lie.

The six-faced octahedrons 1, $\frac{3}{2}$, 3; 1, $\frac{4}{3}$, 4; and 1, $\frac{64}{63}$, 64, fulfil this condition.

When we meet with the edges of the rhombic dodecahedron bevelled by planes of the six-faced octahedron, as shown in Fig. 84; we know that the poles of the six-faced octahedron lie in this zone, and must have its symbol of the form $1, \frac{n}{n-1}, n$.

Draw the arcs $P_3\,r_1$, $P_2\,r_2$, and $P_3\,r_1$, as in Fig. 88. Let a_1 be the point where $r_2\,r_1$ cuts $P_1\,r_6$, a_2 that where $r_1\,r_6$ cuts $r_2\,P_2$, and a_3 that where $r_2\,r_6$ cuts $P_3\,r_1$.

$a_1\,a_2\,a_3$ will be poles of the twenty-four-faced trapezohedron whose symbol is 1 2 2. These lie in the same zone as those of the six-faced octahedrons whose symbols are of the form $1, \frac{n}{n-1}, n$.

When, therefore, the intersections of the rhombic dodecahedron with a twenty-four-faced trapezehedron make parallel edges, as in Fig. 80, we know, without measuring its angles, that the trapezohedron is that whose symbol is 1 2 2.

To Determine the Position of the Poles of the Faces of the Different Forms of the Cubical System on the Sphere of Projection.

The Twenty-four-faced Trapezohedron.—The angles marked θ' under the article "Combination of Cube and Twenty-four-faced Trapezohedron," page 317, will give the circle of latitude which will cut the zone $P_1\,r_6$ in a_1 (Fig. 89) for each form of the trapezohedron, and the angle ϕ' the circle of latitude, which will cut the zones $P_2\,r_2$, and $P_3\,r_1$, in a_2 and a_3, reckoning each circle of latitude from P_1 as the north pole. Thus, for the form 1, 2, 2, a_1 is the point where the circle of latitude 35° 16′ cuts $P_1\,r_6$, and a_2 and a_3 the points where the circle of latitude 65° 54′ cuts $r_2\,P_2$ and $r_1\,P_3$.

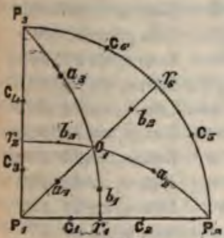


Fig. 89.

Three poles may be similarly described in each of the other octants of the sphere, and thus the poles of the twenty-four faces of the trapezohedron may be placed on the *sphere of projection*.

The Three-faced Octahedron.—Under the article "Combination of Cube and Three-faced Octahedron," page 316, θ' gives the circle of latitude for each particular form of the three-faced octahedron which cuts the zones $r_1\,P_3$, and $r_2\,P_2$, in the poles b_1 and b_3, ϕ' the circle of latitude which cuts the zone $P_1\,r_6$ in b_2.

By means of the angles θ and ϕ', the poles of all the known forms of the three-faced octahedron may be fixed on the *sphere of projection*.

The Four-faced Cube.—Under the article "Combination of Cube and Four-faced Cube," page 318, θ' gives the circle of latitude which cuts the zones $P_1\,P_2$ and $P_1\,P_3$ in the poles of the four-faced cube c_1 and c_3, and ϕ' the circle of latitude which cuts the same zones in the poles c_2 and c_4; the poles c_5 and c_6 are distant from P_2 and P_3 respectively θ' degrees in the zone $P_2\,P_3$.

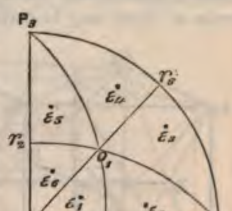


Fig. 90.

We can thus determine the position of the poles of all the known forms of the four-faced cube on the sphere of projection.

The Six-faced Octahedron.—The following table will enable us to fix the poles of the six-faced octahedron on the sphere of projection, considering P_1 (Fig. 90) as the north pole, $P_1\,P_2$ the first meridian of longitude, and $P_2\,P_3$ the equator :—

For the form 1, $\frac{5}{4}$, $\frac{5}{3}$. Latitude of pole $e_1 = 45°$.
Longitude of $e_1 = 36° 52'$.
Latitude of pole $e_2 = 55° 33'$.
Longitude of $e_2 = 30° 58'$.
Latitude of pole $e_3 = 64° 54'$.
Longitude of $e_3 = 38° 39'$.

For the form 1, $\frac{64}{63}$, 64,	Lat. $e_1 = 44° 33'$.	Lat. $e_2 = 45° 27'$.	Lat. $e_3 = 89° 22'$.
	Lon. $e_1 = 0° 55'$.	Lon. $e_2 = 0° 54'$	Lon. $e_3 = 44° 33'$.
For the form 1, $\frac{4}{3}$, 2,	Lat. $e_1 = 42° 2'$.	Lat. $e_2 = 56° 9'$.	Lat. $e_3 = 68° 12'$.
	Lon. $e_1 = 33° 41$.	Lon. $e_2 = 26° 34'$.	Lon. $e_3 = 36° 52'$.
For the form 1, $\frac{14}{11}$, $\frac{16}{7}$,	Lat. $e_1 = 41° 0'$.	Lat. $e_2 = 56° 24'$.	Lat. $e_3 = 69° 23'$.
	Lon. $e_1 = 32° 28'$.	Lon. $e_2 = 25° 1'$.	Lon. $e_3 = 36° 15'$.
For the form 1, $\frac{4}{3}$, 4,	Lat. $e_1 = 38° 20'$.	Lat. $e_2 = 53° 58'$.	Lat. $e_3 = 78° 41'$.
	Lon. $e_1 = 18° 26'$.	Lon. $e_2 = 14° 2'$.	Lon. $e_3 = 36° 52'$.
For the form 1, $\frac{3}{2}$, 3,	Lat. $e_1 = 36° 42'$.	Lat. $e_2 = 57° 41'$.	Lat. $e_3 = 74° 30'$.
	Lon. $e_1 = 26° 34'$.	Lon. $e_2 = 18° 26'$.	Lon. $e_3 = 33° 41'$.
For the form 1, $\frac{5}{3}$, 5,	Lat. $e_1 = 32° 19'$.	Lat. $e_2 = 59° 32'$.	Lat. $e_3 = 80° 16'$.
	Lon. $e_1 = 18° 26'$.	Lon. $e_2 = 11° 19'$.	Lon. $e_3 = 30° 58'$.
For the form 1, 2, 4,	Lat. $e_1 = 29° 12'$.	Lat. $e_2 = 64° 7'$.	Lat. $e_3 = 77° 24'$.
	Lon. $e_1 = 26° 34'$.	Lon. $e_2 = 14° 2'$.	Lon. $e_3 = 26° 34'$.
For the form 1, $\frac{12}{5}$, $\frac{12}{3}$,	Lat. $e_1 = 27° 56'$.	Lat. $e_2 = 66° 19'$.	Lat. $e_3 = 76° 3'$.
	Lon. $e_1 = 30° 58'$.	Lon. $e_2 = 15° 15'$.	Lon. $e_3 = 24° 26'$.
For the form 1, $\frac{16}{7}$, 4,	Lat. $e_1 = 26° 45'$.	Lat. $e_2 = 67° 00'$.	Lat. $e_3 = 77° 6'$.
	Lon. $e_1 = 29° 45'$.	Lon. $e_2 = 14° 2'$.	Lon. $e_3 = 23° 38'$.
For the form 1, $\frac{7}{3}$, 7,	Lat. $e_1 = 24° 19'$.	Lat. $e_2 = 67° 1'$.	Lat. $e_3 = 82° 31'$.
	Lon. $e_1 = 18° 26'$.	Lon. $e_2 = 8° 8'$.	Lon. $e_3 = 23° 12'$.
For the form 1, 4, 8,	Lat. $e_1 = 15° 37'$.	Lat. $e_2 = 76° 4'$.	Lat. $e_3 = 83° 5'$.
	Lon. $e_1 = 26° 34'$.	Lon. $e_2 = 6° 23'$.	Lon. $e_3 = 14° 2'$.

The latitudes of the poles e_6 e_5 and e_4 (Fig. 90) are the same respectively as those of e_1 e_2 and e_3; and the longitudes of e_6 e_5 and e_4 are respectively 45° greater than those of e_1 e_2 and e_3.

Hemihedral Forms of the Cubical System.—It has been already observed (page 294) that, with the exception of the cube and rhombic dodecahedron, another series of forms may be derived from the forms of the cubical system which we have described, by producing half their faces to meet one another after certain laws. These forms, from the method of their derivation, are called *hemihedral*, or half-faced. We shall proceed to describe them.

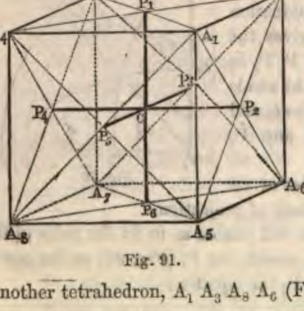


Fig. 91.

The Tetrahedron.—If we describe a cube (Fig. 91) as directed in page 296, the figure whose outline is bounded by the lines A_4 A_2, A_4 A_5, A_4 A_7, A_2 A_7, A_2 A_5, (Fig. 92) A_5 A_7, will be a tetrahedron, formed by the development of the faces of the octahedron opposite to the angular points A_1 A_3 A_6 and A_8 of the cube. This is called the *positive tetrahedron.* Another tetrahedron, A_1 A_3 A_8 A_6 (Fig. 93) may be formed by the development of the faces of the octahedron opposite to the angular points A_2 A_4 A_5 and A_7 of the cube. This tetrahedron is precisely similar to the former in magnitude, but differs

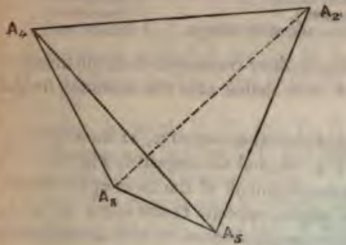


Fig. 92.

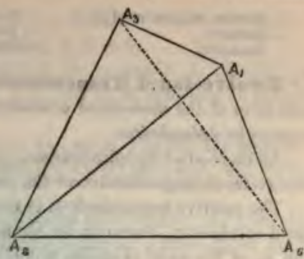


Fig. 93.

from it in its position with regard to the cube in which is is inscribed. It is called the *negative tetrahedron.* With some forms, the combinations of the *positive tetrahedron* are different from those of the *negative* tetrahedron.

Faces, Angles, Edges, &c.—The *tetrahedron* is bounded by four similar and equal plane faces, such as A_1 A_8 A_6 (Fig. 93), each of which is an equilateral triangle. It has four *three-faced solid angles,* which touch the alternate three-faced solid angles of the cube in which it is inscribed; *six equal edges,* one of which corresponds with one diagonal of the face of the cube, for every face; the *cubical axes* join the centres of the opposite edges; one half of each *octrahedral axis* coincides with that of the cube, while the other half is cut by a face of the tetrahedron at a third of its distance from the centre. The adjacent faces of the tetrahedron are inclined to each other at an angle of 70° 32′, and their normals consequently at an angle of 109° 28′.

Symbols.—The symbol for this form is $\frac{111}{2}$. Naumann's symbol for the tetrahedron is $\frac{O}{2}$; Miller's, κ 111; frequently the same symbol is used as for the octahedron, only intimating that it is a hemihedral form.

To describe a net for the Tetrahedron which may be inscribed in a given cube.

Draw a line A_4 A_5 (Fig. 94) equal to the line A_4 A_5 (Fig. 91); on this describe an

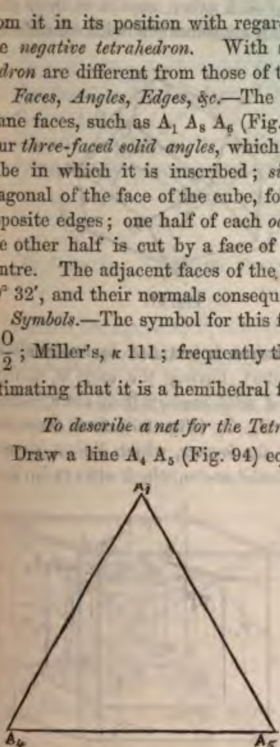


Fig. 94.

Fig. 95.

equilateral triangle A_1 A_4 A_5. This will give a face of the tetrahedron.

Four such faces, arranged as in Fig. 95, will form the required net.

Crystals of the following minerals have faces parallel to the Tetrahedron.

Blende (sulphuret of zinc).	Eulytine (bismuth blende).	Rhodizite.
Boracite.	Fahlerz (gray copper).	Tennantite.
Diamond.	Pharmacosiderite (arseniate of iron).	Tritonite.

Twelve-faced Trapezohedron.—The *twelve-faced trapezohedron* is the hemihedral form of the *three-faced octahedron.* It has been called also the *deltoidal,* or the *trapezoidal dodecahedron.*

As there are two tetrahedrons, one positive and the other negative, so there are two twelve-faced trapezohedrons—the positive one, Fig. 96, and the negative, Fig. 97.

The positive trapezohedron is formed by the development of the faces of the three-faced octahedron, forming its three-faced solid angles opposite to the edges A_1 A_3 A_6 and A_8 of the cube (Fig. 34, p. 303); the negative trapezohedron by the development of the solid angles opposite to the edges A_2 A_4 A_5 and A_7 of the cube (Fig. 34).

These trapezohedrons are in all respects similar to each other, except in their position with respect to their circumscribing cube, and their combinations with other forms.

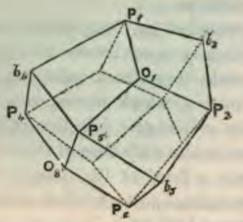


Fig. 96.

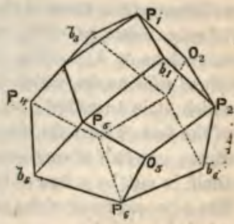


Fig. 97.

Faces, Angles, Edges.—The *twelve-faced trapezohedron* is bounded by *twelve* similar and equal trapeziums, such as b_4 P_1 O_1 P_5 (Fig. 96), having the edge P_1 b_4 equal P_5 b_4, and O_1 P_5 equal O_1 P_1. It has four *three-faced solid angles* which always lie in the octahedral axes of the cube, such as O_1, O_3, O_8, O_6 (Fig. 96), four *three-faced solid angles* b_2, b_4, b_5, b_7 (Fig. 96), more acute than the former, which lie on opposite sides of the same octahedral axes; and six *four-faced solid angles,* which always lie in the extremities of the cubical axes P_1 P_2 P_4 &c. (Fig. 96). There are twelve shorter edges joining the solid angles marked P and O, and twelve longer joining the solid angles indicated by P and B.

Symbols.—The symbol for this form is $\frac{11m}{2}$; Naumann's is $\frac{nO}{2}$; Miller's $\kappa.hhk$.

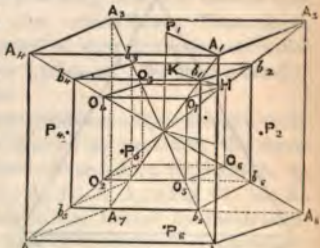


Fig. 98.

To draw the Twelve-faced Trapezohedron.—Make the same construction as for Fig. 33, page 303, and add the following, as in Fig. 98. The letters B_5 and C have been omitted in Fig. 98; they may easily be supplied by a reference to Fig. 33.

In $B_5 A_1$ take a point H, such that $B_5 H = \frac{1}{2-\frac{1}{n}} B_5 A_1$.

Thus if $n=2$ $B_5 H = \frac{1}{2-\frac{1}{2}} B_5 A_1 = \frac{2}{3} B_5 A_1$.

Take C K in $C P_1$ equal to B_5 H. Join $H K_1$ cutting $A_1 C$ in b_1.

Through b_1 draw $b_1 b_2$ parallel to $A_1 A_2$ cutting $C A_2$ in b_2, and $b_1 b_4$ parallel to $A_1 A_4$ cutting $C A_4$ in b_4; and so on till the cube $b_1 b_2 b_3$, &c. b_8, is described as shown in Fig. 98.

Joining the points P_1, P_2, &c., P_6, $O_1 O_8$, &c., $b_2 b_4$, &c., as in Fig. 96, the positive trapezohedron will be described; and joining $P_1 P_2$, &c., P_6, $O_2 O_4$, &c., $b_1 b_3$, &c., as in Fig. 97, the negative trapezohedron.

Axes.—The cubical axes terminate the opposite four-faced solid angles, and coincide with those of the cube. One half of each octahedral axis is cut by a three-faced solid angle at a distance $C O_1 = \frac{1}{2+\frac{1}{n}}$ from the centre C, and the other half by the other three-faced solid angle at a distance $C b = \frac{1}{2-\frac{1}{n}}$ from C.

As n varies from 1 when this form coincides with tetrahedron to ∞ when it coincides with the rhombic dodecahedron, C O increases from a $\frac{1}{3}$rd to $\frac{1}{2}$ of C A, and C b diminishes from C A to $\frac{1}{2}$ C A.

Inclination of Faces of the Twelve-faced Trapezohedron.—If θ be the angle of inclination of two adjacent faces, over an edge P b, and ϕ the angle over the shorter edge P O,

$$\cos. \theta = \frac{n(n-2)}{2n^2+1} \quad \cos. \phi = \frac{n(n+2)}{2n^2+1}$$

To Describe a Net for the Twelve-faced Trapezohedron, which may be inscribed in a given Cube.

Describe the figure $A_1 P_1 C B_5$ (Fig. 99) the same as $A_1 P_1 C B_5$ (Fig. 35) page 303.

Take C K and H B_5, both $= \frac{1}{2-\frac{1}{n}} C P_1$.

Join A_1 C and H K, cutting in b and then join $P_1 b$.

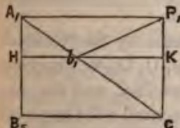


Fig. 99.

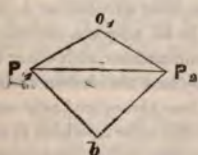


Fig. 100.

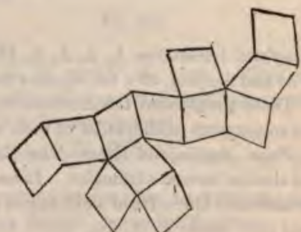


Fig. 101.

Let $P_1 O_1 P_2$ (Fig. 100) be the same triangle as $P_1 O_1 P_2$, Fig. 36, page 304.

On $P_1 P_2$ as a base describe an isosceles triangle $P_1 b P_2$ (Fig. 100), having each of its sides $P_1 b_8$, $P_2 b$, equal $P_1 b$, Fig. 99.

Twelve such figures as O_1 P_1 *b* P_2, arranged as in Fig. 101, will give the required net.

Forms of the Twelve-faced Trapezohedron.—The form $\frac{112}{2}, \frac{20}{2}$ Naumann; κ. 122 Miller; has CO = $\frac{2}{5}$ CA, and C*b* = $\frac{2}{3}$ CA. Inclination of faces over P*b* 90°, that of their normals 90°; over the edge PO 152° 44′, that of their normals 27° 16′.

Faces of this form occur in Blende, Diamond, and Pharmacosiderite.

The form $\frac{11\frac{3}{2}}{2}, \frac{\frac{3}{2}O}{2}$ Naumann; κ.233 Miller; has CO = $\frac{3}{5}$ CA and C*b* = $\frac{3}{4}$ CA. Inclination of faces over the edge P*b* 82° 9′, that of their normals 97° 51′; over the edge PO 162° 40′, that of their normals 17° 20′.

Faces of this form have been observed in Fahlerz.

The Three-Faced Tetrahedron.—The *three-faced tetrahedron* has three faces corresponding to each face of the regular tetrahedron; it is called also the *trigonal dodecahedron*, *triakistetrahedron*, *pyramidal tetrahedron*, and by Haidinger *kuproid*.

This form is derived from the *twenty-four-faced trapezohedron* by the development of half its faces. The faces forming the three-faced solid angles O_1 O_2, &c., opposite the solid angles A_1 A_3 A_6 and A_8 of the cube (Fig. 39, p. 305), producing the *positive*

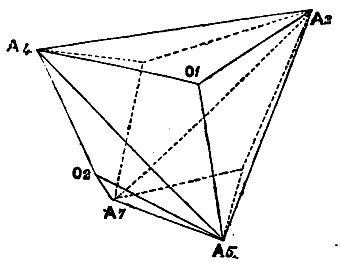


Fig. 102.

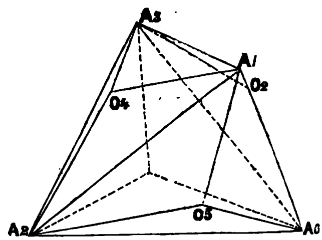


Fig. 103.

three-faced tetrahedron A_2 A_4 A_5 A_7 (Fig. 102); and those opposite the solid angles A_2 A_4 A_7 and A_5 (Fig. 39), the *negative three-faced tetrahedron* A_1 A_3 A_8 A_6 (Fig. 103.)

These three-faced tetrahedrons are, in all respects, similar, except in their position and consequent modification of their combinations with other forms.

Faces, Angles, and Edges—The *three-faced tetrahedron* is bounded by twelve equal and similar isosceles triangles. It has *four three-faced solid angles*, O_1 O_2 &c., opposite the alternate three-faced solid angles of the cube in which it is inscribed, and four *six-faced solid angles* A_2 A_4 &c., which touch the other alternate three-faced solid angles of the cube. The edges are *twelve shorter* AO, AO, &c., joining the three-faced and six-faced solid angles, and *six longer* AA, AA &c., each lying along a diagonal of a face of the cube, and joining the six-faced solid angles together.

Symbols.—The symbol for the *three-faced tetrahedron* is $\frac{1mm}{2}$; Naumann's is $\frac{mOm}{2}$; and Miller's κ.*hhk*.

To draw the Three-faced Tetrahedron.—Describe the same figure as directed (Fig. 39, p. 305), for drawing the *twenty-four-faced trapezohedron.*

Join the points A_1 A_4 O_1 A_5 A_7, &c., as shown in Fig. 102, for the *positive three-faced tetrahedron*, and the points A_1 A_3 O_2 O_4 A_8 O_5, &c., as shown in Fig. 103, for the *negative three-faced tetrahedron.*

Axes.—The *cubical axes* join the centres of the opposite longer edges of the *three-faced tetrahedron;* one half of each octahedral axis coincides with that of the cube, and the other half, as CO is the $\frac{m}{m+2}$th part of CA.

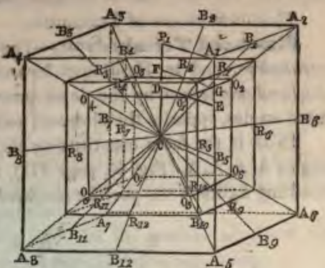


Fig. 104.

Inclination of adjacent Faces.—If θ be the angle of inclination of two faces over one of the longer edges, as A_1 A_3, and ϕ over one of the shorter edges as OA,

$$\text{Cos. } \theta = \frac{m^2 - 2}{m^2 + 2} \quad \cos.\ \phi = \frac{2m + 1}{m^2 + 2}.$$

Limits of Form.—As m increases in value from 1 to ∞, this form varies from that of the tetrahedron to that of the cube, and CO increases from the $\frac{1}{3}$rd to the whole of CA.

To construct a Net of the Three-faced Tetrahedron which can be inscribed in a given Cube.—Draw a face P_1 R_4 O_1 R_1 (Fig. 105), of the *twenty-four faced trapezohedron* from which the *three-faced tetrahedron* is derived, as described in Fig. 42, p. 307.

Fig. 105.

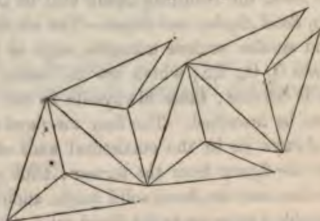


Fig. 106.

Through P_1 draw A_4 A_2 perpendicular to P_1 O_1.

Produce O_1 R_4 to meet P_1 A_4 in A_4; and O_1 R_1 to meet P_1 A_2 in A_2. Then the isosceles triangle O_1 A_4 A_2 will be a face of the required *three-faced tetrahedron;* and twelve such faces, arranged as in Fig. 106, will form the required net.

Forms of the Three-faced Tetrahedron.— The form $\frac{122}{2}, \frac{2O2}{2}$ Naumann, κ. 112 Miller; has CO $= \frac{1}{2}$ CA. Inclination of faces over the longer edge AA 109° 28′, that of their normals 70° 32′; over the shorter edge OA 146° 27′, normals 33° 33′

This form occurs in Boracite, Eulytine, Fahlerz, and Tennantite.

The form $\frac{133}{2}, \frac{3O3}{2}$ Naumann, κ. 113 Miller, has CO $= \frac{3}{5}$ CA. Inclination of faces over the longer edge AA 129° 31′, that of their normals 50° 29′; over the shorter edge OA 129° 31′, that of their normals 50° 29′.—This form occurs in Blende and Fahlerz.

The form $\frac{1\frac{3}{2}\frac{3}{2}}{2}, \frac{\frac{3}{2}O\frac{3}{2}}{2}$ Naumann, κ. 223 Miller, has CO $= \frac{3}{7}$ CA. Inclination of faces over the longer edge AA, 93° 22′, that of their normals 86° 38′; over the shorter edge OA, 160° 15′, that of their normals 19° 45′.

This form occurs in Tennantite.

Six-faced Tetrahedron.—The *six-faced tetrahedron*, called also the *hexakis-tetrahedron*, and by Haidinger *boracitoid*, is a hemihedral form derived from the *six-faced octahedron*, by the development of the faces constituting four of its solid six-faced angles, opposite the alternate solid angles of the cube in which it is inscribed.

Thus, if the faces constituting the six-faced solid angles O_1 O_5 O_6 O_8, opposite the angles $A_1 A_5 A_6 A_8$ (Fig. 50, page 311), of the cube, be produced to meet one another, the resulting figure is the *positive six-faced tetrahedron* (Fig. 107). If the faces of the solid

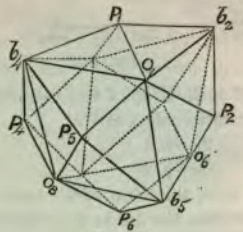


Fig. 107.

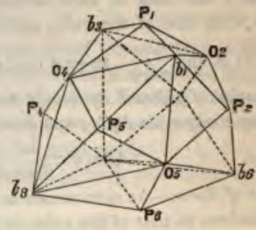


Fig. 108.

ngles O_4 O_2 O_5 O_7, opposite the angles A_2 A_4 A_5 and A_7 (Fig. 50) of the cube be produced to meet, the resulting figure will be the *negative six-faced tetrahedron* (Fig. 109).

Faces, Solid Angles, and Edges.—The *six-faced tetrahedron* is bounded by twenty-four equal and similar scalene triangles, such as P_1 O_1 b_4 (Fig. 107). It has four *six-faced solid angles* O_1 O_6, &c., which are the same as those of the *six-faced octahedron* from which it is derived; these always lie in the octahedral axis of the cube in which the figure can be inscribed. The four *six-faced solid angles* b_2 b_4, &c. more acute than the former, always lie in the octahedral axes of the cube, but on the other side of the centre of the figure from the former; thus each octahedral axis, as A_1 A_7 (Fig. 50) of the cube has one six-faced solid angle, such as O_1, on one side of its centre C, and on the other side a more acute six-faced solid angle b_7. There are six *four-faced solid angles*, P_1 P_2, &c., P_6, which terminate the cubical axes, and touch the cube in which the figure is inscribed in the centre of each face. It has twelve shorter edges joining the four-faced solid angles with the obtuse six-faced solid angles, such as P_1 O_1 (Fig. 107); twelve intermediate joining the four-faced with the acute six-faced solid angles, such as P_1 b_4; and twelve longer joining the acute and obtuse six-faced solid angles, such as O_1 b_4.

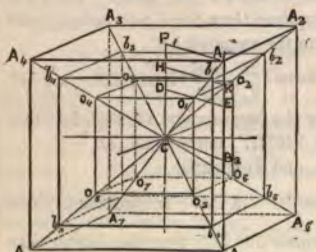


Fig. 109.

To Draw the Six-faced Tetrahedron.—Describe a cube A_1 A_2 A_3 &c., A_8 (Fig. 109); draw its octahedral axes, and in it inscribe a cube O_1 O_2 O_3 &c., O_8, as directed in Fig. 50, page 311, such that $O_1\,O_2 = \dfrac{1}{1+\frac{1}{m}+\frac{1}{n}} A_1\,A_2$.

The letters A_1 B_5 E_1 D and P_1 having the same position in Fig. 109 that they have in Fig. 50, make the following additional construction.

In B_5 A_1 take a point K such that,

$$B_5 K = \frac{1}{1 + \frac{1}{m} - \frac{1}{n}} A_1 B_5.$$

In CP_1 take $CH = B_5 K_1$. Join HK cutting CA_1 in b_1.

Through b_1 draw b_1 b_2 parallel to A_1 A_2 and meeting CA_2 in b_2, and b_1 b_4 parallel to A_1 A_4 meeting CA_4 in b_4, and so on, till a cube b_1 b_2 b_3, &c., b_8 is inscribed in the cube A_1 A_2, &c., A_8 having Cb_1 Cb_2, &c., Cb_8 for its octahedral axes.

Join the points P_1 O_1 b_2 &c., as shown in Fig. 107, for the *positive six-faced tetrahedron*, and P_1 O_2 b_1, &c., as in Fig. 108, for the *negative six-faced tetrahedron*.

Symbols.—The symbol for the *six-faced tetrahedron* is $\frac{1\, m\, n}{2}$, Naumann's $\frac{m\,O\,n}{2}$, and Miller's $\kappa.hkl$.

Axes of the Six-faced Tetrahedron.—The *cubical axes* join the opposite four-faced solid angles, and the *octahedral axes* join the obtuse four-faced solid angles to the acute four-faced solid angles opposite to them; the former at a distance equal to the $\frac{1}{1 + \frac{1}{m} + \frac{1}{n}}$th part of the extremity of the octahedral axis from the centre, and the latter at the $\frac{1}{1 + \frac{1}{m} - \frac{1}{n}}$th part of that distance.

Inclination of the adjacent faces.—If θ be the angle of inclination of two adjacent faces over the edge PO (Figs. 107 and 168), joining the four-faced and obtuse six-faced solid angles,

$$\text{Cos. } \theta = \frac{1 + \frac{2}{mn}}{1 + \frac{1}{m^2} + \frac{1}{n^2}}$$

If ϕ be the angle of inclination over the edge Ob, joining the obtuse and acute six-faced solid angles,

$$\text{Cos. } \phi = \frac{\frac{2}{m} + \frac{1}{n^2}}{1 + \frac{1}{m^2} + \frac{1}{n^2}}$$

If ψ be the angle of inclination over the edge Pb, joining the four-faced and acute six-faced solid angles,

$$\text{Cos. } \psi = \frac{1 - \frac{2}{mn}}{1 + \frac{1}{m^2} + \frac{1}{n^2}}$$

Limits of the form of the six-faced tetrahedron.—As m and n approach in magnitude to unity, the *six-faced octahedron* approximates to the *tetrahedron;* and when m and n

are both equal to unity, it becomes the *tetrahedron*. In this case the six faces forming the obtuse six-faced solid angle, as well as the edges PO and Ob, all lie in the same plane; and the edges, such as $P_1 b_4$ and $P_1 b_2$, in the same straight line.

As m and n increase in magnitude and equality to each other, the *six-faced tetrahedron* approximates to the *cube;* and when m and n are both infinitely great, it coincides with it. In this case the four planes which form each four-faced solid angle lie in the same plane.

As m approaches to unity, while n increases in magnitude, the *six-faced tetrahedron* approximates to the *rhombic dodecahedron*; and when m equals unity, and n is infinitely great, it becomes the *rhombic dodecahedron*. In this case the planes on each side of the edge Ob lie in the same plane.

When m equals unity, while n remains finite, the *six-faced tetrahedron* becomes the *twelve-faced trapezohedron*; and the faces on each side of the edge Ob lie in the same plane.

When m and n are equal to each other, both finite and greater than unity, the *six-faced tetrahedron* becomes the *three-faced tetrahedron*, and the faces on each side of the edge PO lie in the same plane.

When m remains finite, and n becomes infinite, the *six-faced tetrahedron* becomes the *four-faced cube*, and the faces each become equal and similar isosceles triangles.

From the above it will be seen that the *cube*, *rhombic dodecahedron*, and *four-faced cube*, are limiting forms of the hemihedral form, the *six-faced tetrahedron*.

To describe a Net for the Six-faced Tetrahedron which may be inscribed in a given Cube.

Draw $A_1 P_1 B_5 C$ (Fig. 110), intersected by $A_1 C$ and ED, meeting in O_1, as directed for Fig. 52, page 313.

$$\text{Take CH} = \frac{1}{1 + \frac{1}{m} - \frac{1}{n}} P_1 C.$$

Make $B_5 K = CH$. Join KH, cutting $A_1 C$ in b_1.

Join $P_1 O_1$, $P_1 b_1$.

Produce $A_1 B_5$ to A_5 and $P_1 C$, to P_6. Make $B_5 A_5 = A_1 B_5$, $C P_6 = P_1 C$.

Take $B_5 E' = B_5 E$, and $C D' = C D$.

Join $E' D'$, $A_5 P_6$.

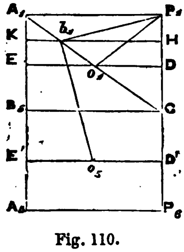


Fig. 110.

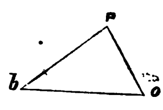


Fig. 111.

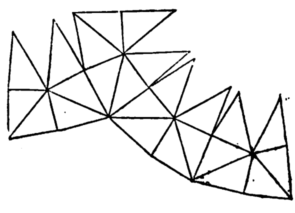


Fig. 112.

In $E' D'$ take $E' O_5 = E O_1$.

Join $b_1 O_5$,

Then Fig. 111, draw $b\, o = b_1 O_5$ of Fig. 110; and on it describe a triangle P b o, having the side P $b = P_1 b_1$, and the side P O $= P_1 O_1$ of Fig. 110.

Then P b o (Fig. 111), is a face of the *six-faced tetrahedron* required, and twenty-four such faces arranged, as in Fig. 112, will give the required net.

Forms of the six-faced Tetrahedron.—The form $\frac{1,\ \frac{5}{3},\ 5}{2}$, $\frac{5,\ O,\ \frac{5}{3}}{2}$ Naumann, and κ. 5, 3, 1 Miller, is the only one which has been observed in nature.

Its obtuse six-faced angles cut the octahedral axes of the cube at a distance $= \frac{5}{9}$, and its acute six-faced angles at a distance $= \frac{5}{7}$ of the centre, from the extremity of the octahedral axis.

$$\theta = 152^\circ\ 20^\circ\ \phi = 152^\circ\ 20', \text{ and } \psi = 122^\circ\ 53'.$$

Faces parallel to this form have been observed in crystals of *boracite.*

Hemihedral Forms with inclined Faces.—The preceding hemihedral forms which we have considered, may be referred to the tetrahedron as their type, and may all be derived, as we have shown, from the *six-fixed tetrahedron;* none of these forms have a face parallel to any other face of the same form. There are two hemihedral forms with parallel faces.

Hemihedral Forms with Parallel Faces.—One hemihedral form with parallel faces is derived from the *four-faced cube,* and is a *twelve-faced pentagon;* the other is obtained from the *six-faced octahedron,* and is a *twenty-four faced trapezohedron.*

The Pentagonal Dodecahedron.—The *pentagonal dodecahedron,* called also the *pyritoid,* has twelve pentagonal faces, and is a hemihedral form of the *four-faced cube* derived from it, according to the following laws:

The alternate faces of each six-faced solid angle O_1 O_2 O_3, &c., O_8 (Fig. 44, page 308), of the *four-faced cube,* are produced to meet each other.

Thus the faces P_1 O_1 O_4, P_5 O_1 O_5, and P_2 O_1 O_2 (Fig. 44), of the angle O_1, and three similarly situated faces of the other six-faced solid angles, produce the *positive pentagonal*

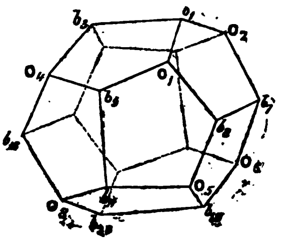


Fig. 113.

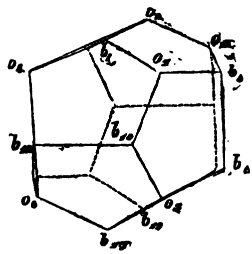


Fig. 114.

dodecahedron (Fig. 113). The remaining faces O_4 O_1 P_5, O_5 O_1 P_2, and O_2 O_1 P_1, and those similarly situated to them, produce the *negative pentagonal dodecahedron* (Fig. 114).

Faces, Solid Angles, and Edges.—This form is bounded by twelve equal and similar pentagonal faces, such as b_1 O_1 b_9 O_4 b_3 (Fig. 113). These pentagonal faces have always four of their edges equal to each other, the fifth, b_1 b_3, generally unequal to the others. The only case in which b_1 b_3 is equal to the others, is that of the *regular pentagonal dodecahedron,* which is one of the *five platonic bodies;* this form has not been observed in nature.

The *pentagonal dodecahedron* has *eight three-faced solid angles* which always lie in the octahedral axes of the cube in which it can be inscribed, $O_1 O_2$ &c. (Figs. 113 and 114).

And *twelve three-faced solid angles* which do not lie in any one of the three species of axes belonging to the cube. They always lie, however, in a face of the circumscribing cube. There are twenty-four edges (Ob) joining the *three-faced solid angles*, bounded by *equal plane angles* lying in the octahedral axes, with the *three-faced solid angles* bounded by *unequal plane angles*, and six edges (bb) joining the two species of *three-faced solid angles* together. These six edges (bb) always lie in a face of the circumscribing cube, in a line passing through the centre of the face parallel to one of its edges, and the cubical axes always pass through the centre of this edge.

Symbols.—The symbol for the *pentagonal dodecahedron* is $\frac{1\ m\ \infty}{2}$, Naumann's $\frac{\infty\ 0\ m}{2}$, and Miller's $\pi.hko$.

To draw the Pentagonal Dodecahedron.—Prick off the points P_1 P_2, &c., P_6, B_1 B_2 B_3, &c., B_{12}, and O_1 O_2 O_3 O_4, &c., O_8, of Fig. 45, page 308.

Join P_1 P_6, P_2 P_4, and P_5 P_3.

Also B_1 B_3, B_2 B_4, B_1 B_9, B_5 B_6, &c., O_1 O_2, O_1 O_4, &c. (Fig. 115).

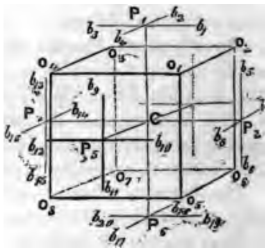


Fig. 115.

Along each of these lines take P_1 b_1, P_2 b_2, &c., $= (\frac{1}{m} - 1)$ P_1 B_1, $(\frac{1}{m} - 1)$ P_2 B_2, &c.

The portions b_1 B_1, b_3 B_3 are omitted in Fig. 115.

Then joining the points b_1 b_3 b_9, with O_1 O_4, b_8 b_{11} b_9, with O_5 O_1, &c., as in Fig. 113, the *positive twelve-faced pentagon* will be delineated. The *negative twelve-faced pentagon* will be drawn by joining O_1 O_2 with b_4 b_2 and b_5, and O_1 and O_5 with b_5 b_{10} and b_6, &c., as in Fig. 114.

Axes.—The *cubical axes* join the centres of the opposite six unequal edges; the *octahedral axes* join the opposite three-faced solid angles contained by equal plane angles.

Inclination of Adjacent Faces.—If θ be the angle of inclination of two adjacent faces measured over the edge bb_1, and ϕ the angle of inclination of adjacent faces over the edge Ob, then

$$\text{Cos. } \theta = \frac{1 - \frac{1}{m_2}}{1 + \frac{1}{m_2}} \text{ and cos. } \phi = \frac{\frac{1}{m}}{1 + \frac{1}{m_2}}.$$

Limits of the Form.—As m increases from 1 to ∞, the *pentagonal dodecahedron* varies from the *rhombic dodecahedron* to the cube. The nearer the *pentagonal dodecahedron* approaches to the *rhombic dodecahedron*, or m to 1, the smaller becomes the edge $b\,b$, till, when $m = 1$, it vanishes altogether; and the greater m becomes, or the form approximates to that of the cube, the nearer the edge $b\,b$ approaches to two, or the length of the edge of the circumscribing cube.

To construct a Net of the Twelve-faced Pentagon which can be inscribed in a given Cube.—The same construction being made (Fig. 116), as directed for Fig. 46, page 309, add the following:—

Let H be the point where E O_1 cuts B_1 P_2.

Take b in B_1 P_1, so that B_1 $b = \frac{1}{m}$ B_1 P_1.

Take C L $= P_1$ b. Join b L, b P_2, the latter cutting E H in M.

Join L M. Take L S $=$ L M. Through S draw S T parallel A_1 B_5; meeting E H in T, and join b T.

Then (Fig. 117) draw P O $=$ P_1 O_1, Fig. 116. On P O describe the triangle P *b* O, having its side *b* O $=$ T *b*, Fig 116, and the side P *b* $=$ P_1 *b*, Fig. 116.

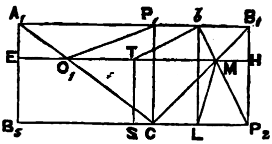


Fig. 116.

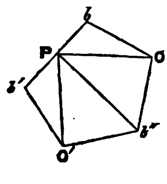


Fig. 117.

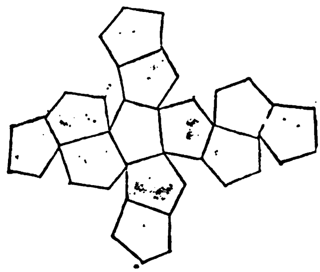


Fig. 118.

On the other side of P O (Fig 117), describe the triangle P *b''*, O having the side O *b''* $=$ T *b*, Fig. 116, and side P *b''* $=$ P_2 *b*, Fig. 116.

On the opposite side of P *b''* describe the figure P *b'* O' *b''*, similar and equal to P *b* O *b''*. Then *b' b* O *b''* O' is a face of the required form, and twelve such pentagonal faces, arranged as in Fig. 118, will give the required net.

Forms of the Pentagonal Dodecahedron.—The form $\frac{1\ 2\ \infty}{2}$, $\frac{\infty\ O\ 2}{2}$ Naumann, and π. 210 Miller, has

$$\theta = 126° 52', \text{ and } \phi = 113° 35',$$

the angles of their normals being 53° 8', and 66° 25'.

This form occurs in crystals of Cobaltine, Gersdorffite, and Pyrite.

The form $\frac{1\ 3\ \infty}{2}$, $\frac{\infty\ O\ 3}{2}$ Naumann, and π. 310 Miller, has

$$\theta = 143° 8', \text{ and } \phi = 107° 27',$$

the angles of their normals being 36° 52', and 72° 33'.

It occurs in Hauderite and Pyrite.

The form $\frac{1\ \frac{3}{2}\ \infty}{2}$, $\frac{\infty\ O\ \frac{3}{2}}{2}$ Naumann, π. 320 Miller, has

$$\theta = 112° 37', \text{ and } \phi = 117° 29',$$

the angles of their normals being 67° 23', and 62° 31'.

Occurs in Pyrite.

The form $\frac{1\ 4\ \infty}{2}$, $\frac{\infty\ O\ 4}{2}$ Naumann, π, 410 Miller, has

$$\theta = 151° 56', \text{ and } \phi = 103° 37';$$

the angles of their normals being 28° 4', and 76° 23'.

It occurs in crystals of Cobaltine.

The Irregular Twenty-four-faced Trapezohedron.—Called the *irregular twenty-four-faced trapezohedron* because its trapezoidal faces have only two edges equal to each other, and to distinguish it from the *twenty-four-faced trapezohedron*, which is a *holohedral form*, and has its four edges equal to each other in pairs. This form is called also the *Trapezoidal icositetrahedron*, the *Dyakis dodecahedron*, the *Diploid*, and the *Diplopyritoid.*

It is derived from the *six-faced octahedron* by the development of half its face according to the following law.

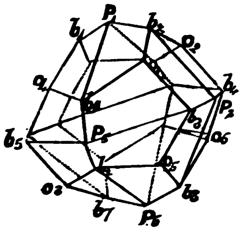


Fig. 119.

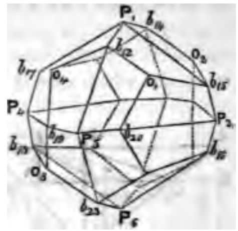


Fig. 120.

Each alternate face of the six-faced solid angle O_1 (Fig. 49, page 311), and the similarly-situated faces of the other seven six-faced solid angles are produced, till they meet to form the *positive twenty-four-faced trapezohedron* (Fig. 119). The remaining faces, when produced, form the *negative twenty-four-faced trapezohdron* (Fig. 120).

Faces, Solid Angles, and Edges.—This form is bounded by twenty-four irregular trapeziums, such as $P_1\ b_2\ o_1\ b_{11}$ (Fig. 119), having only two sides equal, as $o_1\ b_2$ and $o_1\ b_{11}$. It has *six four-faced solid angles*, such as $P_1\ P_2$, &c., P_6, which terminate the opposite extremities of the cubical axes, and touch the centre of each face of the circumscribing cube. Eight *three-faced solid angles*, $o_1\ o_2$, &c., o_8, which always lie in the octahedral axes of the circumscribing cube. Twelve *four-faced solid angles*, $b_1\ b_2$, &c., which do not lie in the cubic, octahedral, or rhombic axes of the cube. It has twelve shorter edges, $P_1\ b_1$, $P_1\ b_2$, &c.; twelve longer, $P_1\ b_{11}$, $P_6\ b_{12}$, &c.; and twenty-four intermediate edges, $o_1\ b_2$, $o_1\ b_{11}$, &c.

Symbols.—The symbol for this form is $\left[\frac{1\ m\ n}{2}\right]$. Naumann $\left[\frac{m\ O\ n}{2}\right]$, and Miller π, $h\ k\ l$.

To Draw the Irregular Twenty-four-faced Trapezohedron.—Prick off the points $P_1\ P_2$, &c., P_6, $o_1\ o_2$, &c., o_8, & C, from Fig. 51, page 312, for the Figs. 121 and 122. Join $C\ P_1\ C\ P_2$, &c., $o_1\ o_2\ o_3$, &c. In $C P_1$, $C P_2$, &c., $C P_6$, take points $e_1\ e_2$, &c., e_6 (Figs. 121 and 122), such that

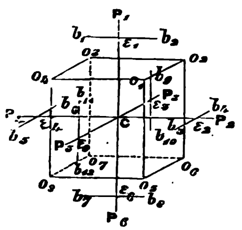


Fig. 121.

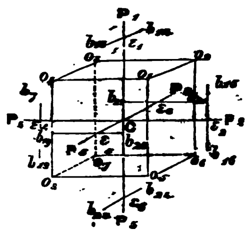


Fig. 122.

$$c\,e = \frac{1-\frac{1}{n}}{1-\frac{1}{mn}}\ C\,P.$$

In Fig. 121, through e_1 and e_6 draw $b_1\ b_2$, and $b_7\ b_8$, parallel to $C\ P_2$; through e_2 and e_4, $b_3 b_4$, and $b_5\ b_6$, parallel to $C\ P_3$; and through e_5 and e_3, $b_{11}\ b_{12}$, and $b_9\ b_{10}$, parallel to $C\ P_1$. Also, in Fig. 122, draw $b_{13}\ b_{14}$, and $b_{23}\ b_{24}$, parallel to $C P_3$; b_{17} and b_{18}, and $b_{15}\ b_{16}$, parallel to $C\ P_1$; and $b_{19}\ b_{20}$, $b_{21}\ b_{22}$, parallel to $C\ P_2$.

Throughout both figures take $e\ b = \frac{1-\frac{1}{n}}{1-\frac{1}{mn}}$ C P, for the lines parallel C P_1 or C P_2, and half that quantity for those parallel C P_3.

Join $P_1\ o_1$, $b_2\ b_{11}$, &c., Fig. 119, for the *positive twenty-four-faced trapezohedron*, and $P_1\ b_{14}\ b_{15}\ o_1\ b_{13}$, &c., Fig. 120, for the *negative twenty-four-faced trapezohedron*.

Axes.—The *cubical axes* join the opposite four-faced solid angles $P_1\ P_2$, &c., P_6, and the *octahedral* the opposite six-faced solid angles, and are equal to the axes of the six-faced octahedron, from which the form is derived.

Inclination of the Adjacent Faces.—If θ be the angle of inclination of two adjacent angles over the shorter edge $P\,b_1$,

$$\cos.\ \theta = \frac{1 - \frac{1}{\;} + \frac{1}{n^2}}{1 + \frac{1}{m^2} + \frac{1}{n^2}}$$

ϕ the angle of inclination of two adjacent faces over the longer edge $P_1\,b_{11}$,

$$\cos.\ \phi = \frac{1 + \frac{1}{m^2} - \frac{1}{n^2}}{1 + \frac{1}{m^2} + \frac{1}{n^2}}$$

And if ψ be the angle of inclination of two adjacent faces over edge $O\,b$,

$$\cos.\ \psi = \frac{\frac{1}{m} + \frac{1}{n} + \frac{1}{mn}}{1 + \frac{1}{m^2} + \frac{1}{n}}$$

Limits of the Form of the Irregular Twenty-four-faced Trapezohedron.—As m and n approach in magnitude to unity, the *irregular twenty-four-faced trapezohedron* approximates to the *octahedron*; and when m and n both equal unity, it becomes the octahedron. In this case the planes constituting the *three-faced solid angle* all lie in the same plane, and the edges, such as $P\,b$ and $b\,P$, are in the same line.

As m and n both increase in magnitude, and finally become infinitely great, this form approximates to and becomes the *cube*. In this case, the four planes forming the *four-faced solid angles* at the extremity of the cubic axes lie in the same plane, and the edges $o\,b$ and $b\,o$ in the same line.

As m approaches to unity while n increases in magnitude, and becomes finally infinitely great, the form approaches that of the *rhombic dodecahedron*; in this case two planes, on each side one of the longer edges $P\,b$, approach to and finally become in one plane, while the shortest edge, $b\,P$, becomes shorter and shorter, and finally vanishes. When m equals unity, while n remains finite, the form becomes the *three-faced octahedron*, and the trapezoidal faces change from trapeziums to isosceles triangles. When m and n equal each other, are both finite and greater than unity, the *irregular twenty-four-faced trapezohedron* becomes the *regular twenty-four-faced trapezohedron*, and the irregular trapeziums regular ones.

When m remains finite, and is greater than unity, and n becomes infinite, the form becomes that of the *pentagonal dodecahedron*, and the planes on each side the longer edge $P\,b$ lie in the same place.

From what has been said of the limits of the above form, it appears that each of the holohedral forms of the cubical system, with the exception of the *four-faced cube* and *six-faced octahedron*, which have their own hemihedral forms with parallel faces, may be regarded as limiting forms of the hemihedral forms with parallel faces.

As yet, the two hemihedral forms with parallel faces have only been observed in nature combined with one another and those of the holohedral forms, with the exception of the *six-faced octahedron* and *four-faced cube*, but never with any of the hemihedral forms with inclined faces.

To describe a Net for the Irregular Twenty-four faced Trapezohedron.—Describe the same figure (Fig. 123) as directed page 313, Fig. 52, with the exception of the lines $G\,R$, $P_1\,R$, $R\,P_2$ and $O_1\,R_5$.

Take C N $= \frac{1 - \frac{1}{n}}{1 - \frac{1}{mn}}$ C P_1 and P_2 R $=$ C N. Join N R.

Also take P_1 K $= \frac{1 - \frac{1}{m}}{1 - \frac{1}{mn}}$ P_1 B_1 and C L $= P_1$ K. Join K L, cutting N R in *b*.

Join P_1 *b*. Let M be the point where E O_1 produced cuts C B_1.
Join L M. Take L S in P_2 B_5 $=$ L M.
Through S draw S T parallel A_1 B_5 meeting E M in T, and join T *b*.

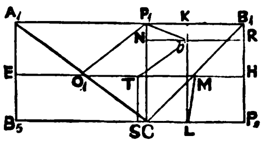


Fig. 123.

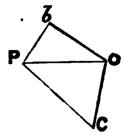


Fig. 124.

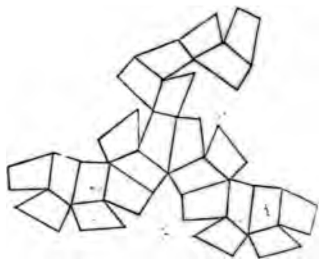


Fig. 125.

Then (Fig. 124) draw P O $= P_1$ O_1 (Fig. 123). On it describe a triangle P *b* O, having the side P *b* $= P_1$ *b* (Fig. 123), and *b* O $=$ T *b* (Fig. 123).

On the other side of P O describe the triangle P C O having the side P C $=$ *b* P_2 (Fig. 123), and O C $=$ *b* T (Fig. 123).

P *b* O C will be the face of the *irregular twenty-four faced trapezohedron*, and twenty-four such faces, arranged as in Fig. 125, will form the required net.

Forms of the Irregular Twenty-four faced Trapezohedron which occur in Nature.—
The form $\left[\frac{1, \frac{5}{4}, \frac{5}{3}}{2}\right]$, $\left[\frac{\frac{5}{3}\ O\ \frac{5}{4}}{2}\right]$ of Naumann, and π 5, 4, 3 of Miller has

$$\theta = 111^\circ\ 6' \qquad \phi = 129^\circ\ 48' \qquad \psi = 160^\circ\ 3'$$

Normals, whose faces are inclined at θ, ϕ, and ψ, 68° 54′; 50° 12′ and 19° 57′. Faces parallel to this form occur in crystals of Pyrite.

The form $\left[\frac{1, \frac{4}{3}, 2}{2}\right]$, $\left[\frac{2\ O\ \frac{4}{3}}{2}\right]$ of Naumann, and π 4, 3, 2 of Miller, has

$$\theta = 112^\circ\ 17' \qquad \phi = 136^\circ\ 24' \qquad \text{and } \psi = 153^\circ\ 43'.$$

Inclination of normals 67° 17′, 43° 36′, and 26° 17′.
Faces parallel to this form occur in Linneite.

The form $\left[\frac{1, \frac{15}{11}, \frac{15}{7}}{2}\right]$, $\left[\frac{\frac{15}{7}\ O\ \frac{15}{11}}{2}\right]$ of Naumann, and π. 4, 3, 2 of Miller, has

$$\theta = 112^\circ\ 47' \qquad \phi = 138^\circ\ 45' \qquad \text{and } \psi = 151^\circ\ 28'.$$

Inclination of normals 67° 13′, 41° 15′, and 28° 32′.
Faces parallel to this form occur in Linneite.

The form $\left[\frac{1, \frac{3}{2}, 3}{2}\right]$, $\left[\frac{3\ O\ \frac{3}{2}}{2}\right]$ of Naumann, and π 3, 2, 1 of Miller, has

$$\theta = 119^\circ\ 4' \qquad \phi = 149^\circ\ 00' \qquad \text{and } \psi = 141^\circ\ 47'$$

Inclination of normals 64° 37′, 31° 00′, and 38° 13′.
Faces parallel to this form occur in Cobaltine, Hauerite, and Pyrite.

The form $\left[\frac{1, \frac{5}{3}, 5}{2}\right], \left[\frac{5\ O\ \frac{5}{3}}{2}\right]$ of Naumann, and π, 5, 3, 1 of Miller, has

$$\theta = 119° 4' \qquad \phi = 160° 32' \qquad \text{and } \psi = 131° 5'$$

Inclination of normals 60° 56′, 19° 28′, and 48° 55′.
Faces parallel to this form occur in Pyrite.

The form $\left[\frac{1, 2, 4}{2}\right], \left[\frac{4\ O\ 2}{2}\right]$ of Naumann, and π, 4, 2, 1 of Miller, has

$$\theta = 128° 15' \qquad \phi = 154° 47' \qquad \text{and } \psi\ 131° 49'.$$

Inclination of normals 51° 45′, 25° 13′, and 48° 11′.
Faces parallel to this form occur in Pyrite.

Combination of the Cube and Tetrahedron.—When the faces of the *cube* P P, &c. (Fig. 126), predominate, the alternate solid angles of the cube are replaced by four triangular planes, O O, &c., which are parallel to those of the

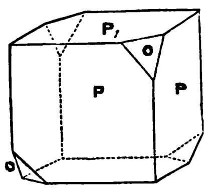


Fig. 126.

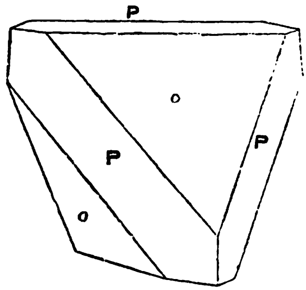


Fig. 127.

inscribed *tetrahedron.* When the faces O O, &c. (Fig. 127), of the *tetrahedron* predominate, each solid edge of the tetrahedron is replaced or truncated by a plane of the cube P_1 P, &c.

Combination of Cube and Twelve-faced Trapezohedron.—When the faces of the *cube* P P, &c. (Fig. 128), predominate, the alternate solid angles of the cube are replaced by an obtuse three-faced solid angle *b b b* of the trapezohedron, pre-

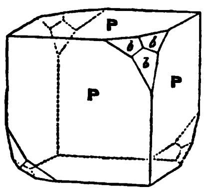


Fig. 128.

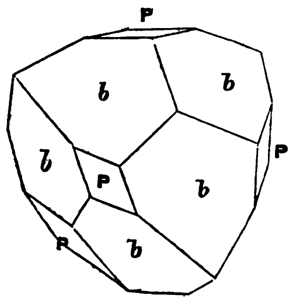


Fig. 129.

senting three trapeziums for each solid angle replaced. When the faces of the twelve-faced *trapezohedron* *b b b* (Fig. 129) predominate, each four-faced solid angle of the trapezodedron is replaced by a rhomboidal plane of the cube P P, &c.

Combination of Cube and Three-faced Tetrahedron.—When the faces of the *cube* P P, &c. (Fig. 130), predominate, the alternate solid angles of the cube are

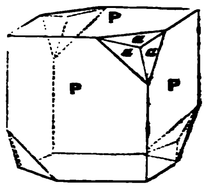


Fig. 130.

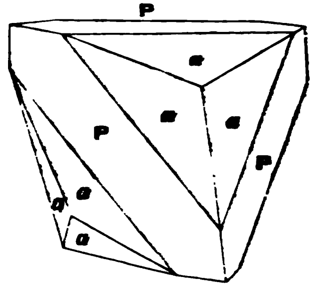


Fig. 131.

replaced by a three-faced solid angle of the three-faced tetrahedron, presenting three triangular planes *a a a* for each solid angle replaced.

When the faces of the *three-faced tetrahedron* *a a a* predominate (Fig. 131), the six longer edges of the three-faced tetrahedron are replaced by a plane of the cube P P P.

Combination of Cube and Six-faced Tetrahedron.—When the faces of the *cube* P P, &c. (Fig. 132), predominate, the alternate solid angles of the cube are each replaced by a six-faced solid angle *e e e*, &c., of the six-faced tetrahedron, consequently each alternate solid angle of the cube is replaced by six triangular planes.

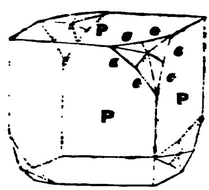


Fig. 132.

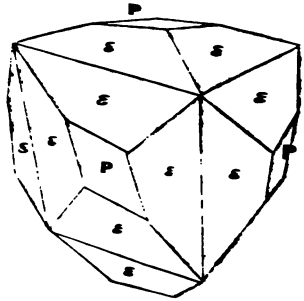


Fig. 133.

When the faces of the *six-faced tetrahedron* *e e e* (Fig. 133) predominate, each four-faced solid angle of the the three-faced tetrahedron is replaced by a rhombic plane P P, &c., of the cube.

In the preceding combinations, it will be seen by comparing Figures 126, 128, 130, and 132 with 55, 60, 62, and 66, that *half* the solid angles of the cube are replaced by the same planes, when combined with the hemihedral forms with inclined faces; that *all* are when combined with their corresponding holohedral forms.

Combination of the Positive and Negative Tetrahedron.—In this combination (Fig. 134), the four three-faced solid angles of the positive *tetrahedron* o o, &c., whose faces predominate, are replaced by triangular planes o′ o′, &c., of the negative tetrahedron. The four faces of the predominating tetrahedron o o, &c., are irregular hexagons. As the faces o′ o′, &c., become larger, three edges of the hexahedron diminish; and when o′ o′, &c., becomes so great that these edges disappear, the combination resolves itself into the regular *octahedron*.

This combination occurs in crystals of Blende (sulphuret of zinc), Boracite, Helvin, and Tennantite.

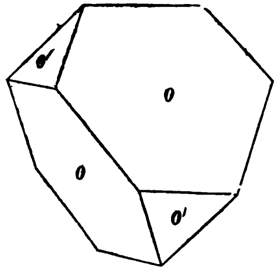


Fig. 134.

Combination of the Tetrahedron and Rhombic Dodecahedron.—In this combination (Fig. 135), the three-faced solid angles of the *tetrahedron* are each replaced by a three-faced solid angle of the *rhombic dodecahedron;* so that we have each solid angle of the tetrahedron replaced by three triangular faces r r r, of the rhombic dodecahedron, each triangular face being an isosceles triangle. When the faces of the *rhombic dodecahedron* predominate, half its three-faced solid angles are replaced by triangular planes of the tetrahedron, like those represented in Fig. 69.

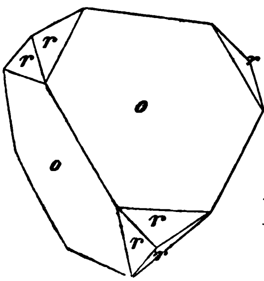


Fig. 135.

Combination of the Tetrahedron and Twelve-faced Trapezohedron.—When the faces of the *twelve-faced trapezohedron* b b b, &c. (Figs. 136 and 137), predominate, the obtuse three-faced solid angles of the *positive twelve-faced trapezohedron* are replaced by triangular planes o o, &c., of the *positive tetrahedron* (Fig. 136), and its

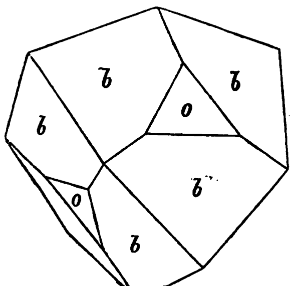


Fig. 136.

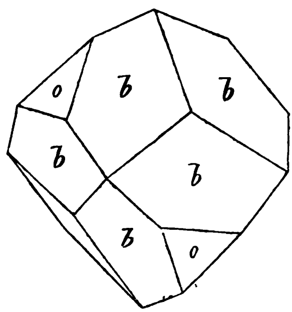


Fig. 137.

acute three-faced solid angles by triangular planes o o, &c. (Fig. 137), of the *negative tetrahedron*.

When the faces of the *positive tetrahedron* *o o*, &c. (Figs. 138 and 139), predominate, the three-faced solid angles of the *positive tetrahedron* are replaced by the acute three-faced solid angles *b b b*, &c., of the *positive twelve-faced trapezohedron* (Fig. 138), and by the obtuse three-faced solid angles *b b b*, &c., of the *negative twelve-faced trapezohedron* (Fig. 139.)

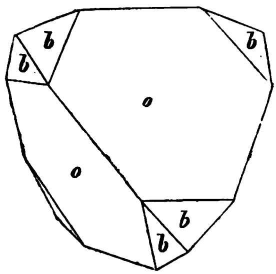


Fig. 138.

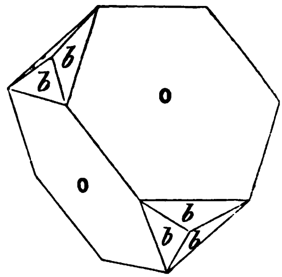


Fig. 139.

In Figs. 136 and 137, the faces of the tetrahedron *o o*, &c., are equilateral triangles; those of the trapezohedron *b b*, &c., irregular pentagons. In Figs. 138 and 139, the faces of the tetrahedron *o o*, &c., are irregular hexagons, and those of the trapezohedron *b b*, &c., isosceles triangles.

Combination of the Tetrahedron and Three-faced Tetrahedron.—When the faces of the *positive three-faced tetrahedron* *a a a*, &c. (Figs. 140 and 141), predominate, the three-faced solid angles of the *three-faced tetrahedron* are replaced by

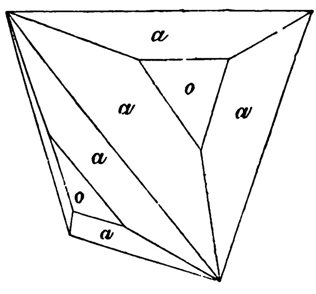


Fig. 140.

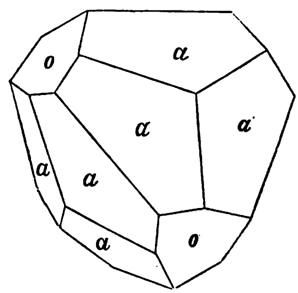


Fig. 141.

triangular planes *o o*, &c. (Fig. 140) of the *positive octahedron*, and its six-faced solid angles by irregular pentagonal planes of the *negative tetrahedron* *o o*, &c. (Fig. 141.)

When the faces of the *positive octahedron o o*, &c. (Figs. 142 and 143), predominate, its solid edges are each replaced by two planes of the *positive three-faced tetrahedron*, as *a a*, &c. (Fig. 142), and its three-faced solid angles by three trapezoidal

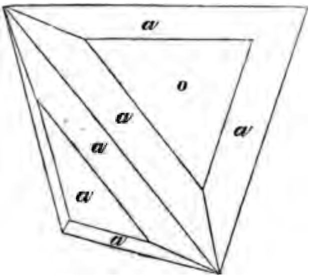


Fig. 142.

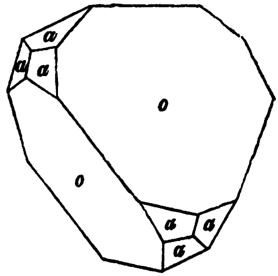


Fig. 143.

planes *a a*, &c. (Fig. 143), forming the three-faced solid angles of the *negative three-faced tetrahedron.*

Combination of the Tetrahedron and Six-faced Tetrahedron.—When the faces of the *six-faced tetrahedron e e e*, &c. (Figs. 144 and 145), predominate, the obtuse six-faced solid angles of the *six-faced tetrahedron* are each replaced by an irre-

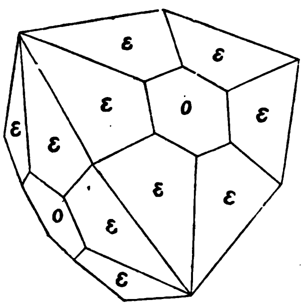


Fig. 144.

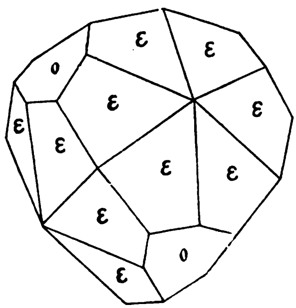


Fig. 145.

gular hexagonal plane *o o*, &c. (Fig. 144), of the *positive tetrahedron;* while its *acute* six-faced solid angles are each replaced by an irregular hexagonal plane *o o*, (Fig. 145), of the *negative tetrahedron.*

When the faces of the tetrahedron predominate, each three-faced solid angle of the tetrahedron is replaced by six planes constituting the *acute* six-faced solid angle of the *positive six-faced tetrahedron*, or by six planes constituting the *obtuse* six-faced solid angle of the *negative six-faced tetrahedron.*

Combination of Rhombic Dodecahedron and Twelve-faced Trapezohedron.—When the faces of the *twelve-faced trapezohedron b b*, &c. (Fig. 146), predominate, the acute three-faced solid angles of the *three-faced trapezohedron* are each replaced by three planes of the *rhombic dodecahedron r r*, &c., which form one of its three-faced solid angles. When the faces of the *rhombic dodecahedron* predominate, the alternate three-faced solid angles of the rhombic dodecahedron are replaced by the obtuse three-faced solid angles of the *twelve-faced trapezohedron.*

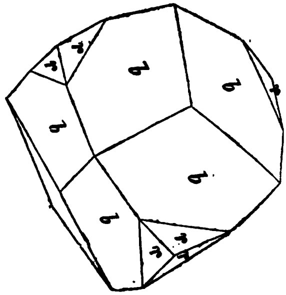


Fig. 146.

Combination of Rhombic Dodecahedron and Three-faced Tetrahedron.—Figures 147 and 148 show the combinations of the *rhombic dodecahedron* with

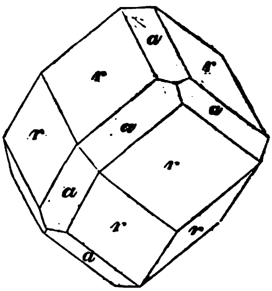


Fig. 147.

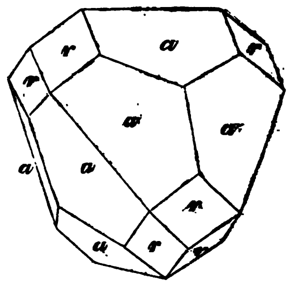


Fig. 148.

the *three-faced tetrahedron,* whose symbol is $\frac{122}{2}$; and Fig. 149 its combination with

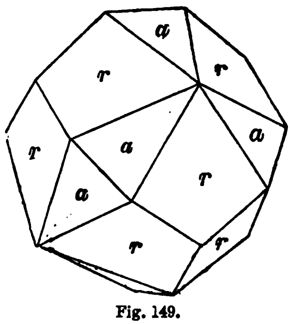


Fig. 149.

the *three-faced tetrahedron* whose symbol is $\frac{133}{2}$. In Fig. 147, where the faces *r r*, &c., of the *rhombic dodecahedron* predominate, the edges of the four-three-faced solid angles of the rhombic dodecahedron, opposite the three-faced solid angles of the *three-faced tetrahedron* are replaced by planes *a a* of the latter. In Fig. 148 the six-faced solid angles of the *three-faced tetrahedron* are each replaced by a three-faced solid angle of the *rhombic dodecahedron.* In Fig. 149 each four-faced solid angle of the *rhombic dodecahedron* is replaced by two planes, *a a*, of the *three-faced tetrahedron.*

Combination of Rhombic Dodecahedron with Six-faced Tetrahedron.—Figs. 150 and 151 represent the combinations of the *rhombic dodecahedron* with the *six-faced tetrahedron* whose symbol is $\frac{1\ \frac{3}{2}\ 3}{2}$, the faces marked *r* being those of the *rhombic dodecahehron*, and those marked *e* the faces of the *six-faced tetrahedron*. In Fig. 150 the three-faced solid angles of the *rhombic dodecahedron*, opposite to the

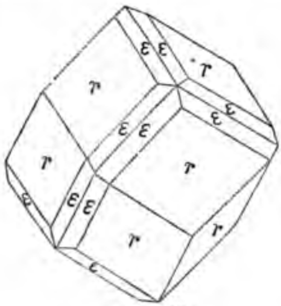


Fig. 150.

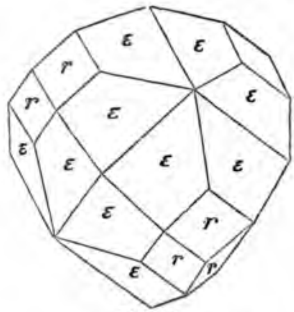


Fig. 151.

obtuse six-faced solid angles of the six-faced tetrahedron, have their edges replaced by two planes of the six-faced tetrahedron. In Fig. 151 where the faces of the *six-faced tetrahedron* predominate, the acute six-faced solid angles of that form are each replaced by a three-faced solid angle of the rhombic dodecahedron.

Combination of Cube with the Pentagonal Dodecahedron.—When the faces of the *cube* (P P, &c.,) predominate (Fig. 152), the edges of the cube are each replaced by a plane *c c*, &c., of the pentagonal dodecahedron. This combination is

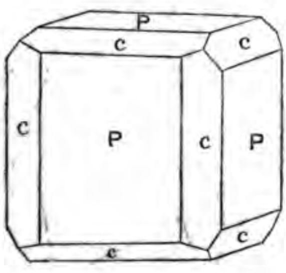


Fig. 152.

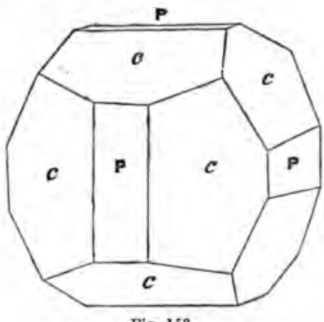


Fig. 153.

distinguished from that of the rhombic dodecahedron with the cube by the inclination of P on *c*, not being 135°. When the faces of the *pentagonal dodecahedron*, *c c*, predominate (Fig. 153), the edges of that form through which the cubical axes pass, are replaced by rectangular planes P P, &c., of the cube.

Combination of the Cube with the Hemihedral form of the Six-faced Octahedron with parallel faces.—When the faces of the *cube* P P, &c. (Fig. 154), predominate, the solid angles of the cube are each replaced by a three-faced solid angle,

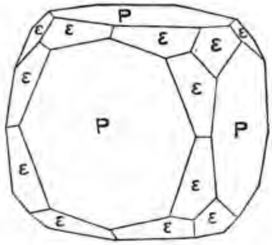


Fig. 154.

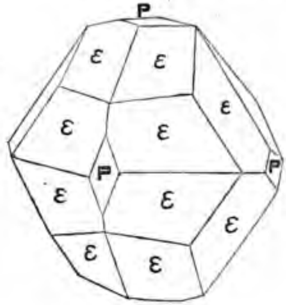


Fig. 155.

e e e, of the trapezohedron. When the faces *e e e*, &c., of the *trapezohedron* (Fig. 155) predominate, the four-faced solid angles of that form which terminate the cubical axes are each replaced by a plane P of the cube.

Combination of the Octahedron and Pentagonal Dodecahedron.—When the faces of the *octahedron o o*, &c. (Fig. 156) predominate, each four-faced solid angle of that form is replaced by two planes, *c c*, of the *pentagonal dodecahedron*. When the faces of the *pentagonal dodecahedron*, *c c*, &c. (Fig. 158), predominate, each of its three-faced solid angles which lie in the octahedral axes is replaced by a triangular plane, *o o*, of the octahedron. When the faces of the octahedron *o o*, &c. (Fig. 157), so

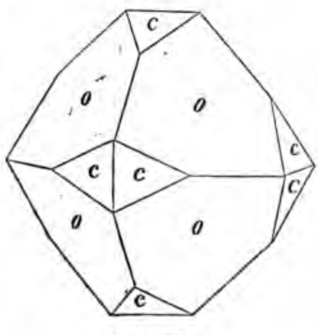


Fig. 156.

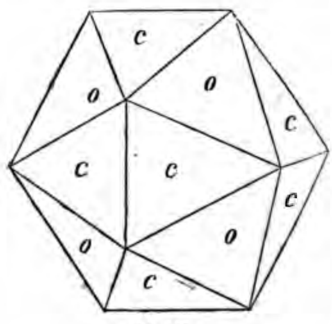


Fig. 157.

far prevail that their angular points touch each other, the combination presents the form shown in Fig. 157, bounded by eight equilateral triangles, *o o*, &c., and twelve isosceles triangles, *c c*, &c.

Platonic Bodies.—If the pentagonal dodecahedron be bounded by twelve regular pentagons,—that is, pentagons whose sides and angles are all equal,—it is called the *regular pentagonal dodecahedron.* In this case the isosceles triangles, *c c*, &c. (Fig 157), are equilateral triangles; and the combination of the regular pentagonal dodecahedron with the octahedron is a regular solid, bounded by twenty similar and equal equilateral triangles, and is called the *icosahedron.*

The tetahedron, cube, octahedron, regular pentagonal dodecahedron, and the icosahedron, are the only *regular* solids which can be formed; a regular solid being one that is bounded by equal and similar regular rectilineal figures. These five solids are called the *platonic bodies.* The regular pentagonal dodecahedron and the icosahedron have not been observed among crystals.

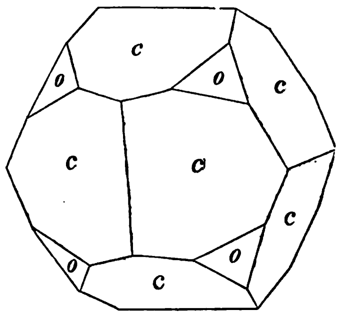


Fig. 158.

"The ancient geometricians made a great many geometrical speculations respecting these bodies; and they form almost the whole subject of the last books of Euclid's Elements. They were suggested to the ancients by their believing that these bodies were endowed with mysterious properties, on which the explanation of the most secret phenomena of nature depended."—*Ozanam's Mathematical Recreations.*

Combination of the Octahedron with the Hemihedral form of the Six-faced Octahedron with parallel faces.—When the faces *o o*, &c., of the *octahedron* (Fig. 159) predominate, its solid angles are each replaced by four planes, *e e e e*, of the

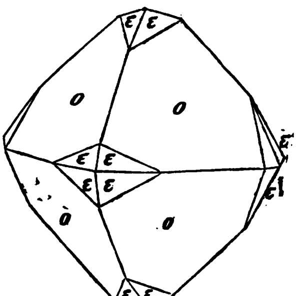


Fig. 159.

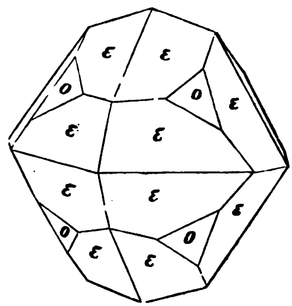


Fig. 160.

trapezodedron. When the faces of the *trapeozedron e e*, &c. (Fig. 160), predominate, each of its three-faced solid angles is replaced by a triangular plane, *o*, of the octahedron.

Combination of the Rhombic Dodecahedron with the Pentagonal Dodecahedron.—When the faces *r r*, &c., of the *rhombic dodecahedron* (Fig. 161)

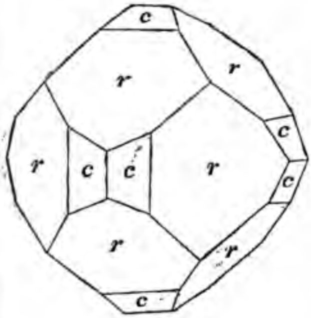


Fig. 161.

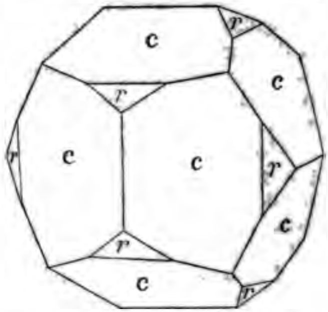


Fig. 162.

predominate, its four-faced solid angles are each replaced by two planes, *c c*, of the pentagonal dodecahedron. When the faces of the pentagonal dodecahedron, *c c*, &c. (Fig. 162), predominate, its four-faced solid angles are each replaced by a triangular plane, *r r*, &c., of the rhombic dodecahedron.

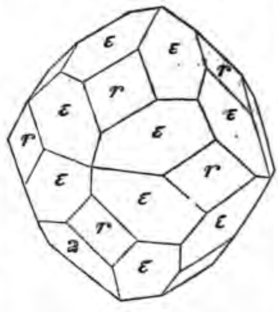


Fig. 163.

Combination of the Rhombic Dodecahedron with the Hemihedral form of the Six-faced Octahedron with parallel faces.—In this combination, the four-faced solid angles of the trapezohedron, *e e* (Fig. 163), are each replaced by a plane, *r r*, &c., of the rhombic dodecahedron.

Complex Combination of Hemihedral Forms.—A crystal of Fahlerz, or grey copper ore, is represented in Fig. 164 as an instance of a complex combination of the hemihedral forms. The faces marked P are those of the *tetahedron; f* those of the *cube; l* are the faces of the *positive three-faced tetrahedron;* and *r* those of the *negative three-faced tetrahedron*, which are both derived from the twenty-four-faced trapezohedron, whose symbol is 12 2. *o* are faces of the *rhombic dodecahedron*; *n* those of the *twelve-faced trapezohedron*, whose symbol is $\frac{1\ 1\ \frac{3}{2}}{2}$; lastly, those marked *s* are the twenty-four faces of the seventh form which enters into this combination, and is the *four-faced cube* whose symbol is 1 3 ∞. This combination has seventy different faces.

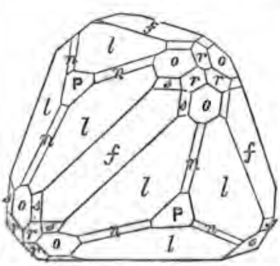


Fig. 164.

Molecules.—Under the head of cleavage, we have seen that crystals of many substances split in directions parallel to certain crystalline forms; thus Galena splits into rectangular fragments parallel to the sides of a *cube ;* Fluor spar, into octahedral or tetrahedral particles parallel to the planes of the *regular octahedron ;* and Blende (sulphuret of zinc), in particles parallel to the faces of a *rhombic dodecahedron.* To this cleavage there appears no limit but the practical difficulty of applying an instrument to the minute particles so as to split them. In the case of Calcite (carbonate of lime), which cleaves in obtuse rhomboids, it is found that the finest dust to which this substance can be reduced presents, under a powerful microscope, nothing but perfect though minute rhomboids. From these circumstances Haüy deduced the theory that the ultimate molecules, or particles of matter of Galena, were minute cubes; those of Fluor spar, regular tetrahedrons; of Blende, irregular tetrahedrons, having their faces parallel to three planes of the rhombic dodecahedron; and generally, that all crystals were composed of molecules whose forms might be determined from their cleavage, or inferred by analogy from their crystalline forms when the cleavage could not be discovered. These hypothetical solids Haüy calls the *primitive* solids of the substances from which they are deduced. Taking this *primitive* solid for his *primary* form, he deduces all the other crystalline forms in which the substance occurs from it, according to certain laws of *decrement*—that is, supposing his primary form to be composed of a large number of minute *primitive solids,* arranged together in a mass of the same form as themselves, he conceives the secondary forms to be derived from the primary one, by abstracting certain groups of these primitive solids, in regular order, from its solid angles and edges.

Law of Decrements.—Galena occurs in the forms both of the octahedron and rhombic dodecahedron as well as the cube. Haüy supposes these forms to be built up entirely of minute cubical particles, and formed from the cube by abstracting rows of cubical particles according to certain laws.

Decrements on Edges.—*Rhombic Dodecahedron.*—If a single row of cubical particles be removed from the edge of the large cubical mass, then two rows adjacent to the one removed, then three more rows adjacent to these, and so on, as in Fig. 165. If we conceive these cubical particles to be so small that the edges formed by their removal could not be perceived, the cubical mass would present the appearance of its edge being cut off by a plane, *a b c d,* Fig. 165, or r_1, Fig. 166. Let the process be

Fig. 165.

Fig. 166.

Fig. 167.

repeated on every edge of the cube, as in Fig. 166, and carried still further by the removal of more rows of cubical particles, as in Fig. 167, at length the form of the rhombic dodecahedron will appear.

Instead of producing the rhombic dodecahedron from the cube by decrements of the cubical molecules, we might suppose it built upon the cube by the addition of layers of these molecules; each successive layer being one row less, all the way round, than its preceding one, as shown in Fig. 168.

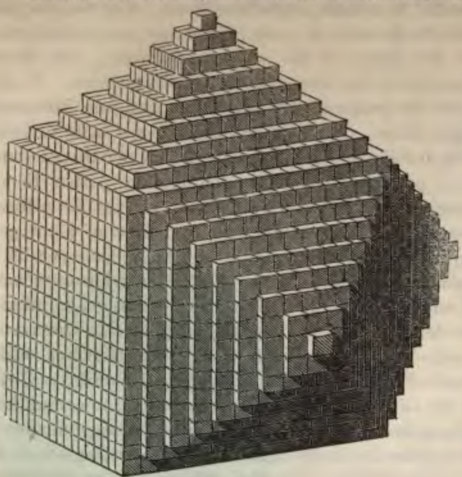


Fig. 168.

Marking the edges of the cube by the letters B, as in Fig. 18, the law of decrement for the formation of the rhombic dodecahedron is represented by the symbol B^1, the 1 above the B indicating the abstraction of single rows of cubical molecules parallel to the edges of the cube.

Four-faced Cube. — If we remove particles from the edge consisting of rows two in height and one in breadth, as in Fig. 169, the edge of the cube will be replaced by a plane, *a b c d*, corresponding to the plane e_1, Fig. 170. Considering P_2 as the upper

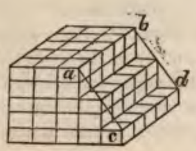


Fig. 169.

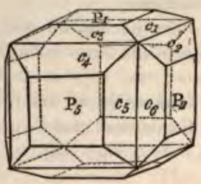


Fig. 170.

Fig. 171.

surface of the cube, similar rows of particles might be abstracted parallel to the edge between P_2 and P_1, producing the plane e_2. Repeating the process for every edge of the cube, we should have the form Fig. 170; and, abstracting equally more rows according to the above law, parallel to every edge, Fig. 65, we should ultimately form the four-faced cube.

The symbol for this decrement is $B^{\frac{1}{2}}$; the figure $\frac{1}{2}$ indicating that rows of molecules, one in breadth and two in height, are abstracted symmetrically in every possible manner from every edge of the cube.

$B^{\frac{m}{n}}$ would indicate a law of decrement by rows of particles *m* in breadth and *n* in height.

Fig. 172 represents the decrements which produce the *pentagonal dodecahedron*, which is the hemihedral form of the four-faced cube, whose symbol, according to Haüy's notation, is $B^{\frac{1}{2}}$. It is formed by decrements of rows along the edges of the cube two in height.

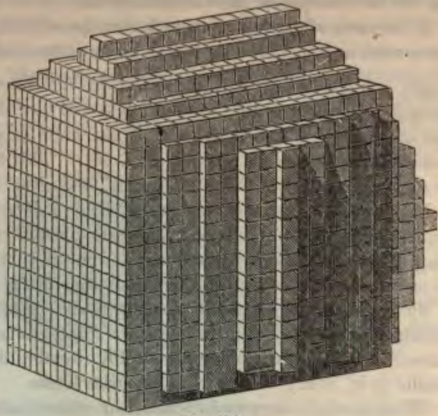


Fig. 172.

Decrements on the angles of the primary form.—If a single cubical molecule be removed from one of the solid angles of the cube, then the row of cubical molecules which touched the ones removed, then the next row which touched these, and so on, the solid angle of the cube would be replaced by a single plane, *a b c* (Fig. 173).

This law of decrement gives rise to the eight planes, o_1 o_2, &c., o_8, Figs. 55, 56, 57, producing the octahedron. The solid angles of the cube being indicated by the letter A, as in Fig. 14. The symbol for this decrement is A^1, the decrements from the solid angle being one in breadth and one in height.

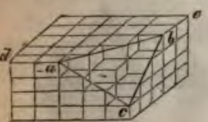


Fig. 173.

If the decrements from the solid angle consist of rows of groups of particles *m* in breadth and *n* in height, the symbol will be $A^{\frac{m}{n}}$.

When *n* is greater than *m*, or the height of each group greater than its breadth, a triangular plane *a b c* (Fig. 174), which is an isosceles triangle, having its sides greater than its base, replaces the solid angle of the cube and corresponds to the plane *b*

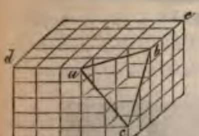


Fig. 174.

Fig. 175.

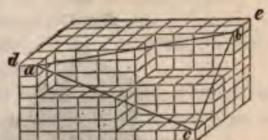


Fig. 176.

(Fig. 60). Since it is perfectly arbitrary on which face we suppose the cube to stand, by altering its position the same law would produce two similar planes b_2 and b_3, so that the solid angle would be replaced by the planes b_1 b_2 and b_3. Supposing every solid angle replaced by similar planes, this law of decrement gives rise (Figs. 60 and 61) to the *three-faced octahedron*.

When *n* is less than *m*, or the groups are less in height than breadth, the solid angle of the cube is replaced by an isosceles triangle *a b c* (Fig. 175), whose base is greater than its sides, corresponding to the plane a_1 (Fig. 62). This law of decrement replaces every solid angle of the cube by three planes a_1 a_2 a_3 (Fig. 62), producing, as shown by Fig. 63, the *twenty-four faced trapezohedron.*

If the rows of particles removed from the solid angle consist of groups, such as those represented in Fig. 176, where each group is two cubical molecules in breadth, three in height, and four in length, the symbol for the decrement will be $B^{\frac{1}{2}}$, $B^{\frac{1}{3}}$, $B^{\frac{1}{4}}$, and the triangular plane replacing the solid angle will be a scalene triangle. According to the laws of symmetry, each solid angle of the cube may be replaced by six such triangles producing the planes e_1 e_2, &c., e_6 (Fig. 66). This law of decrement is that by which the *six faced octahedron* (Figs. 66 and 67) is derived from the cube.

Mr. Brooke, whose modifications of Haüy's decrements we have given above, in his treatises on Crystallography, considers all substances whose crystals occur in any of the forms of the cubical system, as derived from the cube according to these laws, regarding the cube without reference to their cleavages as the primitive form of all.

By decrements of octahedral or tetrahedral particles from the edges and angles of the octrahedron, when the cleavage of a substance is octahedral and of irregular tetrahedrons from the edges and angles of the rhombic dodecahedron when the cleavage is parallel to it, Haüy derives all their other forms.

When a cube is supposed to consist of cubical molecules, the faces of these molecules

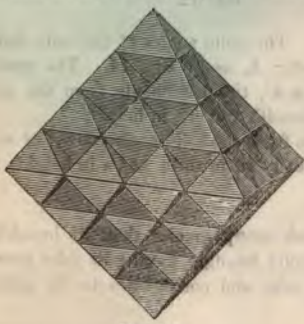


Fig. 177.

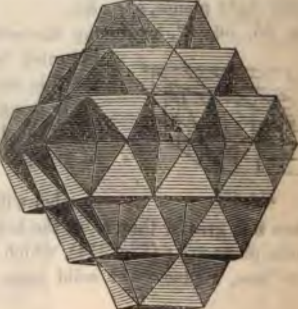


Fig. 178.

Fig. 179.

Fig. 180.

touch each other so as to leave no interstices, just as a solid wall is built up with bricks. If an octahedron be composed of octahedral molecules (Fig. 177), they can only touch each other's edges, leaving tetrahedral spaces. Similarly a tetrahedron (Fig. 179) consisting of octahedral molecules must have tetrahedral spaces between them. An octahedron (Fig. 178) and tetrahedron (Fig. 180) composed of tetrahedral molecules will have octahedral spaces left between the molecules.

Spherical and Spheroidal Molecules.—Hooke and Wollaston contend that the ultimate molecules of substances crystallizing in forms of the cubical system are perfect spheres. Fig. 181 shows the arrangement of these spheres which produces the octahedron; Fig. 182, the tetrahedron; and Fig. 183, the cube. According to this

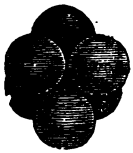


Fig. 181.

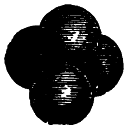


Fig. 182.

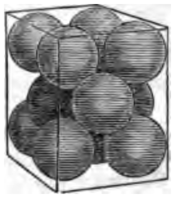


Fig. 183.

Fig. 184.

theory, the sphere may be substituted for the cube in every one of the cubical decrements we have described.

They derive the forms of the other systems of crystals from the combinations of prolate and oblate spheroids (Fig. 184).

Crystallographers generally have now abandoned these theories of the forms of the ultimate molecules of crystalline substances, on account of the numerous difficulties which a more extended view of the science has presented to their reception. They are now interesting as the means by which the relations of the faces of the crystalline forms to their axes were discovered, and we have given the outline of them, because they have had such a powerful influence on the nomenclature, and becomes so incorporated in the technical language of Chemistry and Mineralogy.

SECOND SYSTEM—THE PYRAMIDAL.

This system is called the *pyramidal* or *tetragonal* if its forms are derived from the *octahedron on a square base*, or *double four-faced pyramid;* the *square prismatic*, or *quadratic*, if derived from the *right prism on a square base*. It is also called the *monodimetrical*, or *two and one axial* system, from the properties of its axes.

The *holohedral forms* of this system are,—two *right prisms on a square base*, two *double four-faced pyramids*, the *double eight-faced pyramid*, and the *right prism on an octagonal base*.

From each of these, with the exception of the prisms on a square base, *hemihedral* forms are produced by the development of half their faces, and from one of the hemihedral forms of the *double eight-faced pyramid*, by the development of half its faces, a form is produced having only a fourth of the faces of the original form; this is called a *tetartohedral*, or *fourth-faced* form.

The hemihedral forms with inclined faces are the *sphenoid* or *tetrahedron*, the *eight-faced trapezohedron*, and the *scalenohedron*.

The hemihedral forms with parallel faces,—a *double four-faced pyramid*, and a *prism on a square base*.

The tetartohedral form is a *tetrahedron* or *sphenoid*.

Alphabetical List of the Minerals belonging to the Pyramidal System, together with the Angular Elements from which their Typical Form and Axes may be derived.

Anatase (Pyramidal Titanium)	60° 38′.
Apophyllite	51° 21′.
Autunite	51° 25′.
Braunite	54° 19′.
Calomel	60° 9′.
Cassiterite	33° 55′.
Chiolite	47° 8′.
Edingtonite	43° 39′.
Fanjasie	52° 45′.
Fergusonite	55° 40′.
Gehlenite	Unknown.
Hausmannite (Pyramidal and Manganese Earth)	58° 57′.
Idocrase (Pyramidal Garnet)	28° 9′.
Lanthanite (Carbonate of Cerium)	Unknown.
Matlockite	60° 26′.
Mellite	36° 44′.
Naggagite (Black Tellurium)	61° 23′.
Phosgenite (Murio-carbonate of Lead)	47° 20′.
Rutile (Oxide of Titanium)	32° 47′.
Sarcolite	41° 35′.
Scapolite	23° 45′.
Scheelite	56° 1′.
Somervillite	32° 51′.
Stolzite (Tungstate of Lead)	57° 27′.
Tin	21° 5′.
Torberite	51° 25′.
Towanite (Pyramidal Copper Pyrites)	44° 34′.
Wulfenite (Molybdate of Lead)	57° 33′.
Zenotine (Phosphate of Yttria)	41° 0′.
Zircon	32° 38′.

The Square Prism.—The square prism, also called the tetragonal prism and the right prism on a square base, is a solid form bounded by six faces, four of which are rectangular parallelograms, such as $A_1 A_2 A_5 A_6$ (Fig. 185), forming the sides of the prism, and the other two—its top and bottom—are squares.

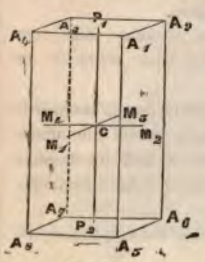


Fig. 185.

By some writers, the four faces alone which are parallelograms are considered the faces of the *square prism*; it is then called an open form, and the two square faces which are required to enclose it are considered distinct forms, under the name of *basal pinacoids*.

Axes of the Square Prism and the Pyramidal System.—Let P_1 and P_2 be the centres of the squares $A_1 A_2 A_3 A_4$, and $A_5 A_6 A_7 A_8$, which enclose the square prism; $M_1 M_2 M_3$ and M_4 the centres of the four rectangular faces. Join $P_1 P_2$, $M_1 M_3$, $M_2 M_4$ cutting each other in C.

The three lines, $M_1 M_3$, $M_2 M_4$, and $P_1 P_2$, which are at right angles to each other, are the *axes* of the *square prism*, and also of the *pyramidal system*.

Parameters.—The base of the square prism, and consequently the length of the equal axes C M_1 and C M_2, is perfectly arbitrary; the height of C P_1, or the height of the prism when a length has been chosen for C M_1 or C M_2, depends upon the angular element already given for each mineral belonging to this system. This angular element is determined from the angular measurement of some pyramid or octahedron whose faces occur most frequently among the crystals of any particular substance.

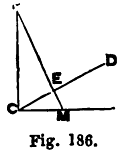


Fig. 186.

To determine C P_1, draw C M and C P (Fig. 186) at right angles to each other; take C M any convenient length, as the *arbitrary unit* of the system of axes.

Through C draw C D, making an angle with C P equal to the angular unit of the substance whose axes are to be represented.

Thus, for Anatase the angle P C D will be 60° 38′; for Apophyllite, 51° 21′; for Calomel, 60° 9′; and so on for other substances belonging to the pyramidal system.

From M let fall M E perpendicular to C D, and produce M E to meet the line C P in the point P.

The distances C M_1, C M_2, and C P_1, Fig. 185, of the points M_1 M_2 and P_1 from C thus determined, are called the *parameters* of the pyramidal system.

It appears, therefore, that the *axes* of the pyramidal system are *rectangular*, and two of its *parameters* are *equal.*

The edges of the *basal pinacoids*, or the breadth of the sides of the *square prism*, are twice the length of the equal parameters C M_1 or C M_2, and the height of the prism or its edge, such as $A_1 A_5$ (Fig. 185) is twice the length of C P.

To draw the square Prism.—Draw the line A_8 A_5 (Fig. 185) equal to twice C M (Fig. 186).

Through A_8 draw A_8 A_7, making an angle of about 30° with A_8 A_5.

Make A_8 A_7 equal half A_8 A_5. Through A_5 draw A_5 A_6 equal and parallel to $A_8 A_7$.

Through A_8 draw A_8 A_4 perpendicular to A_8 A_5, and equal twice C P (Fig. 186).

Through A_5 A_6 and A_7, draw A_5 A_1, A_6 A_2 and A_7 A_3 parallel and equal to A_4 A_8.

Join A_4 A_3, A_4 A_1, A_1 A_2, and A_3 A_2 and the square prism will be represented in perspective.

Symbols.—Each face of the *Square Prism* we have described, cuts one of the axes at a distance from the centre C of the axes, equal to the length of one of the equal parameters, and is parallel to the other two axes. The *two basal pinacoids* cut the axis at a distance equal to the *unequal parameter* and are parallel to the other two axes. Adopting, therefore, the same principle we have used in the cubical system, our symbol for this *square prism* will be 1 ∞ ∞, and for the *Basal Pinacoid* ∞ ∞ 1.

For this *square prism* Naumann's symbol is ∞ P ∞, Miller's 1 0 0, Brooke and Levy's modification of Haüy M, and Moh's [P + ∞].

For the *basal pinacoid* Naumann's is *o* P, Miller's 0 0 1, Brooke and Levy's P, and Mohs P — ∞.

To describe a net for the Square Prism.—Take the parallelogram $A_1\ A_4\ A_5\ A_8$ (Fig. 185) for one of the faces of the square prism, range four such parallelograms as in Fig. 187. Describe two squares having their sides equal to $A_1\ A_4$ (Fig. 185) and place them as in Fig. 187, and the net will be formed.

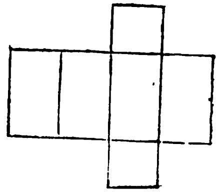


Fig. 187.

Minerals whose crystals present faces parallel to the square prism whose symbol is $1\ \infty\ \infty$:—

Apophyllite.
Cassiterite.
Calomel.
Edingtonite.
Gehlenite.
Idocrase.
Lanthanite.
Mellite.
Naggagite.
Phosgenite.
Rutile.
Sarcolite.
Scapholite.
Sommervillite.
Tin.
Torberite.
Towanite.
Wulfenite.
Zenotine.
Zircon.

Minerals whose crystals cleave parallel to this form,—those printed in italics indicating that the cleavage is easy and perfect :—

Cassiterite.
Calomel.
Edingtonite.
Gehlenite.
Phosgenite.
Rutile.
Scapolite.
Sommervillite.
Zenotine.

Minerals whose crystals present faces parallel to the basal pinacoids:—

Anatase.
Apophyllite.
Braunite.
Cassiterite.
Calomel.
Fergusonite.
Gehlenite.
Hausmanite.
Idocrase.
Lanthanite.
Matlockite.
Mellite.
Naggagite.
Phosgenite.
Rutile.
Sarcolite.
Scapolite.
Scheelite.
Sommervillite.
Stolzite.
Torberite.
Towanite.
Wulfenite.

Cleavages parallel to the basal pinacoids occur in the following minerals:—

Anatase.
Apophyllite.
Gehlenite.
Hausmannite.
Idocrase.
Lanthanite.
Naggagite.
Phosgenite.
Sommervillite.
Stolzite.
Torberite.
Towanite.
Wulfenite.

To draw the Second Square Prism.—Draw the axes $P_1\ P_2$, $M_1\ M_3$, and $M_2\ M_4$ as in Fig. 185. Through $M_1\ M_2\ M_3$ and M_4, draw $B_1\ B_5$, $B_2\ B_6$, $B_3\ B_7$, and B_4 B parallel and equal to P_1 P_2. Join B_1 B_2, B_2 B_3, &c., and a second square prism will be described in a different position from the former one.

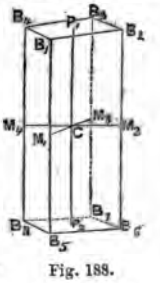


Fig. 188.

In this prism the axes in which the equal parameters lie, pass through its edges, while in the prism previously described they are perpendicular to its faces.

This prism, like the former, is an open form, closed by the same basal pinacoids perpendicular to the axis P_1 P_2.

Symbols.—Each face of this prism cuts two of the axes at a distance equal to that of the equal parameters from the centre C, and is parallel to the third. Thus the plane B_1 B_2 B_5 B_6 cuts the axes C M_1 and C M_2 in the points M_1 and M_2, and is parallel to C P_1. The symbol, therefore, which represents this relation of the faces of the prism to the axes is 1 1 ∞.

Naumann's symbol is ∞ P, Miller's 1 1 0, Brooke and Levy's g^1, Moh's P + ∞. This form being in all respects similar to that of the preceding square prism, except in the breadth of its faces, and its position with regard to the axes, its net will be described in the same manner as Fig. 187.

Faces parallel to the Square Prism whose Symbol is 1 1 ∞, *occur in the following minerals :—*

Anatase.	Phosgenite.	Stolzite.
Apohyllite.	Rutile.	Tin.
Cassiterite.	Sarcolite.	Torberite.
Calomel.	Scapolite.	Towanite.
Idocrase.	Scheelite.	Wulfenite.
Matlockite.	Somervillite.	Zircon.
Naggagite.		

The following Minerals have cleavages parallel to the Square Prism whose Symbol is 1 1 ∞ :—

Cassiterite.	Phosgenite.	Scapolite.
Idocrase.	Rutile.	Zircon.
Matlockite.		

Double Four-Faced Pyramid of the First Order.—The double four-faced pyramid, or octahedron on a square base, is a solid bounded by eight triangular faces, such as P_1 G_1 G_4, Fig. 189, each face being an isosceles triangle ; it has four *four-faced solid angles*, G_1 G_2 G_3 G_4, formed by the equal angles of the isosceles triangles, and two *four-faced solid angles*, P_1 and P_2, formed by the unequal angles of the isosceles triangles. Four equal edges, G_1 G_2, &c.. which are the bases of the isosceles triangles, and eight other edges, P_1 G_1, P_1 G_2, &c., equal to one another, but unequal to the former, which are the sides of the isosceles triangles.

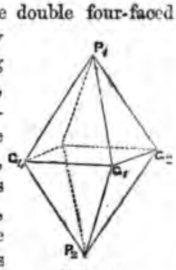


Fig. 189.

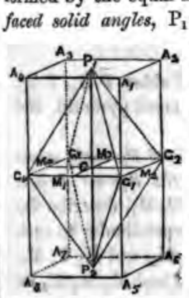


Fig. 190.

To Draw the Double Four-Faced Pyramid of the First Order.—Describe the square prism A_1 A_2, &c., A_8, with its axes P_1 P_2, &c., as directed for Fig, 185.

Through M_1 M_2 M_3 and M_4, Fig. 190, draw G_4 G_1, G_1 G_2, G_2 G_3, and G_3 G_4, parallel to A_4 A_1, A_1 A_2, A_2 A_3, and A_3 A_4, and cutting the edges of the prism in the points G_1 G_2 G_3 and G_4.

Join $P_1\ G_1$, $P_1\ G_2$, $P_1\ G_3$, &c., as in Fig. 190, and the pyramid will be drawn.

Axes.—From the description of this pyramid it is evident that the axes in which the equal parameters are taken join the centres of the edges $G_1\ G_2$, $G_2\ G_3$, $G_3\ G_4$, and $G_4\ G_1$, which are the edges of the bases of two equal square pyramids which joined together form the figure, while the third axis joins the apices $P_1\ P_2$ of the pyramids.

Symbols.—Each face of this double pyramid cuts one axis at a distance equal that of one of the equal parameters, the second axis at a distance equal to the unequal parameter, and is parallel to the third axis.

Thus the face $P_1\ G_1\ G_2$, Fig. 190, cuts the axis $C\ M_2$ in M_2, is parallel to the axis $C\ M_1$, and cuts the axis $C\ P_1$ in P_1.

The symbol which expresses this relation to the axes is $1 \infty 1$.

Naumann's symbol for this form is $P\infty$, Miller's 1 0 1, Brooke and Levy's b^1, and Moh's $P - 1$.

Inclination of the Faces.—Let ϕ be the inclination of the adjacent faces measured over the edges $G_1\ G_2$, &c., θ their inclination over the edges $P_1\ G_1$, &c., and α the angular element given, page 360.

$$\text{Then tan. } \frac{\pi - \phi}{2} = \text{cot. } \alpha \text{ and cos. } \pi - \theta = \left(\text{sin. } \frac{\pi - \phi}{2}\right)^2.$$

are the formulæ from which these inclinations may be determined.

To Describe a Net of the Double Four-Faced Pyramid whose Symbol is $1 \infty 1$.—Describe a square, $G_1\ G_2\ G_3\ G_4$, Fig. 191, having its sides equal to twice $C\ M_2$, Fig. 190, or equal to twice the length of one of the equal parameters. This square will be the base of the double pyramid. Let C be its centre. Join $C\ G_1$, $C\ G_2$, $C\ G_3$, and $C\ G_4$. Then (Fig. 192), draw $C\ P$ perpendicular to $C\ G$. Take $C\ P = C\ P_1$, Fig. 190, and $C\ G = C\ G_1$, Fig. 191. Join $P\ G$.

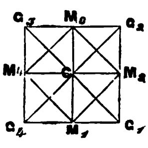


Fig. 191.

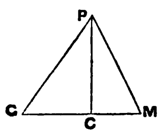


Fig. 192.

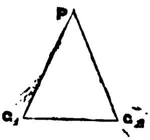


Fig. 193.

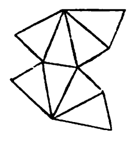


Fig. 194.

Draw $G_1\ G_2$, Fig. 193, equal to $G_1\ G_2$, Fig. 191.

On $G_1\ G_2$ describe an isosceles triangle, $P_1\ G_1\ G_2$, having its equal sides, $P\ G_1$, $P\ G_2$, equal to $P\ G$ (Fig. 192). $P\ G_1\ G_2$ will be a face of the double four-faced pyramid, and eight such faces arranged, as in Fig. 194, will give the required net.

To Draw a Map of the projection of the Poles of the Double Four-Faced Pyramid whose Symbol is $1 \infty 1$, *upon the Sphere of Projection, as well as those of the Square Prisms already described.*—With P_1 as centre, and any convenient radius $P_1\ M_1$, describe the circle $M_1\ M_2\ M_3$. Let $M_1\ M_4$, and $M_2\ M_3$, be any two diameters perpendicular to each other, $d_1\ d_3$, and $d_2\ d_4$, two diameters bisecting the right angles $M_1\ P_1\ M_2$, and $M_2\ P_1\ M_4$. Then P_1 will represent the north pole of the sphere of projection, and $M_1\ M_2\ M_3$ its equator.

P_1 will represent the pole of the basal pinacoid. M_1 M_2 M_3 M_4 the poles of the faces of the square prism whose symbol is 1 ∞ ∞, d_1 d_2 d_3 and d_4 those of the faces of the square prism whose symbol is 1 1 ∞.

The poles a_1 a_2 a_3 a_4 of the double four-faced pyramid, whose symbol is 1 ∞ 1, always lie where the circle of their latitude cuts the meridians C M_1, C M_2, C M_3, and C M_4; their latitude being equal to the angular element of the substance to which the crystal belongs.

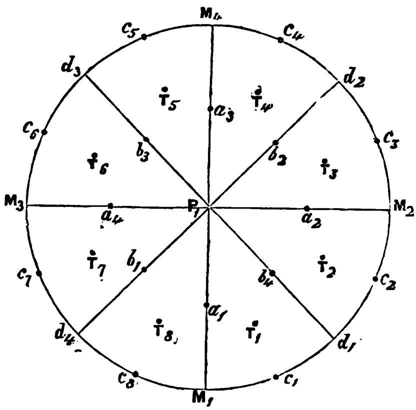


Fig. 195.

Crystals whose Faces occur parallel to the Double Four-Faced Pyramid, whose symbol is 1 1 ∞, together with the latitude of their poles on the sphere of projection.

Anatase	60° 38′
Braunite	54° 20′
Cassiterite	33° 55′
Calomel	60° 9′
Edingtonite	43° 39′
Fanjasite	52° 45′
Hausmannite	58° 57′
Idocrase	28° 9′
Matlockite	60° 26′
Mellite	36° 44′
Naggagite	61° 23′
Phosgenite	47° 20′
Rutile	32° 47′
Sarcolite	41° 35′
Scapolite	23° 45′
Scheelite	56° 1′
Somervillite	32° 51′
Stolzite	57° 27′
Tin	21° 5′
Torberite	51° 25′
Towanite	44° 34′
Wulfenite	57° 33′
Zenotine	41° 0′
Zircon	32° 38′

Three of these minerals cleave parallel to the form 1 1 ∞, Anatase, Braunite, and Cassiterite, the first two with a perfect cleavage.

Double Four-Faced Pyramid of the Second Order.—This pyramid differs from the former only in the position and size of its base. The same figure being described (Fig. 197) as Fig. 185.

Join $M_1 M_2$, $M_2 M_3$, $M_3 M_4$, and $M_4 M_1$; also join $P_1 M_1$, $P_1 M_2$, $P_1 M_3$, $P_1 M_4$, and $P_2 M_1$, $P_2 M_2$, $P_2 M_3$, $P_2 M_4$.

And the *double four-faced pyramid*, $P_1 M_1 M_2 P_2$, Figs. 196 and 197, of the second order, will be inscribed in the square prism.

In this prism, the axes in which the equal parameters lie, join the solid angles at the base of the pyramids $M_1 M_3$, and $M_2 M_4$.

In Fig. 191, let $M_1 M_2 M_3 M_4$ be the centres of the sides of the square.

Join C M_1 C M_2, &c., C M_4, and $M_1 M_2$, $M_2 M_3$, $M_3 M_4$, and $M_4 M_1$.

Then $M_1 M_2 M_3 M_4$ will represent the common base of the pyramids of the second order, $G_1 G_2 G_3 G_4$ that of the pyramids of the first order, and $M_1 M_2$, and $M_3 M_4$, the position of the axes with respect to these bases.

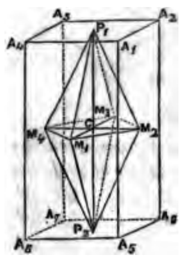


Fig. 196.

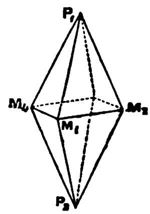


Fig. 197.

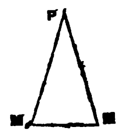


Fig. 198.

To find the face of this form, produce G C to M (Fig. 192). Make C M equal to C M_1, Fig. 191. Join P M.

Draw $M_1 M_2$, Fig. 198, equal to $M_1 M_2$, Fig. 191.

On it describe the isosceles triangle, P $M_1 M_2$, having the equal sides P M_1, P M_2 equal to P M, Fig. 192 P $M_1 M_2$ will be a face of the pyramid.

Eight such triangular faces, arranged as in Fig. 194, will form the net of the *double four-faced pyramid of the second order*

Symbols.—Every face of this form cuts the three axes at distances from its centre equal to that of the parameters; the symbol which expresses this relation is 1 1 1.

Naumann's symbol is P, Miller's 1 1 1, Brooke and Levy's a', Moh's P.

Inclination of Faces.—If ϕ be the angle of inclination of adjacent faces over the edges $M_1 M_2$, $M_2 M_3$, &c., θ that over the edges $P_1 M_1$, $P_2 M_2$, &c., and α that of the angular element, page 360.

$$\tan. \frac{\pi - \phi}{2} = \cot. \alpha \cos. 45^\circ.$$

$$\cos. (\pi - \theta) = \left(\frac{\sin. \pi - \phi}{2}\right)^2.$$

Position of the Poles of this Form on the Sphere of Projection.—The latitude of the poles of this form is the same for all, four lying in the same parallel of north latitude, and four in the same parallel of south latitude. Four poles lie in the zone passing *through the pole* P_1 of the form ∞ ∞ 1, and the poles d_1 and d_2 of the square prism, ose symbol is 1 1 ∞. Thus $b_1\ b_2\ b_3\ b_4$, Fig. 195, represent the poles of the double ır-faced pyramid, whose symbol is 1 1 1.

Faces parallel to this form occur in the following minerals, the angles are the latitude of their poles :—

Anatase	68° 18′
Apophyllite	60° 32′
Calomel	67° 55′
Cassiterite	43° 33′
Chiolite	56° 43′
Fergusonite	64° 41′
Hausmannite	49° 36′
Idocrase	37° 7′
Matlockite	68° 9′
Mellite	46° 33′
Naggagite	68° 56′
Phosgenite	56° 54′
Rutile	42° 20′
Sarcolite	51° 27′
Scapolite	31° 54′
Scheelite	64° 31′
Stolzite	65° 42′
Tin	28° 36′
Towanite	54° 20′
Wulfenite	65° 47′
Zircon	42° 10′

Of these, Fergusonite, Hausmannite, Stölzite, Wulfenite, and Zircon, have *cleavages* rallel to this double four-faced pyramid.

Double Four-Faced Pyramids derived from the Form 1 ∞ 1.—Retaining the same base $G_1\ G_2\ G_3\ G_4$, Fig. 190. Take C P_5 and C P_6, Fig. 199, equal to *m* times C P_1, Fig. 190, *m* being any fraction or whole number greater than unity. Join $P_5\ G_1$, $P_5\ G_2$, &c., as in Fig. 199, and the pyramid will be constructed.

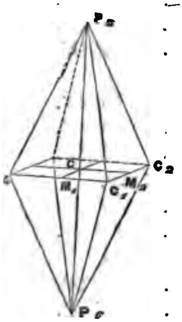


Fig. 199.

For Fig. 200 take C P_3, C P_4 = *m* C P_1 Fig. 190, *m* being a fraction less than unity.

Join $P_3\ G_1$, $P_3\ G_2$, &c., as in Fig. 200, and the pyramid will be constructed.

The series of pyramids, such as Fig. 199, are more acute, and those of Fig. 200 more obtuse, than the original pyramid 1 ∞ 1.

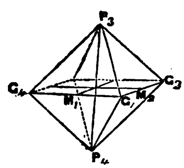


Fig. 200.

Symbols.—The symbol for these double four-faced pyramids is 1 ∞ *m*, as each ce cuts one axis at a distance equal to one of the equal parameters, is parallel to the her, and cuts the third at a distance equal to *m* times the greater parameter.

Naumann's symbol is *m* P ∞, Miller's *h o l*, Brooke and Levy's, $b^{\frac{1}{m}}$.

Poles.—The poles of these pyramids always lie in the zone M P M, Fig. 195, th of the acute pyramids being between *a* and M, those of the obtuse between P and the poles of the upper pyramid lie in the same circle of north latitude, those of t lower in the same circle of south latitude.

Axes.—The axes C M_1, C M_2, &c., in which the equal parameters are taken, jo the centres of sides of the base, Fig. 199 and 200, while the third joins the apices the two pyramids.

Inclination of Faces.—If ϕ be the angle of inclination of adjacent faces over th edges $G_1 G_2$, $G_1 G_4$, &c., θ that over the edges $P_5 G_1$, $P_5 G_4$, &c., and a the angular eleme of the substance,

$$\text{Tan. } \frac{\pi - \phi}{2} = \frac{1}{m} \cot. a$$

$$\text{Cos. } (\pi - \theta) = \left(\sin. \frac{\pi - \phi}{2}\right)^2$$

Forms of the double four-faced pyramid whose symbol is 1 ∞ *m which have been observ in nature, together with the latitude of their poles on the sphere of projection.*

The form 1 ∞ $\frac{1}{5}$, $\frac{1}{5}$ P ∞ Naumann; 105 Miller; and b^5 Brooke and Levy.

Anatase	19° 34′.
Apophyllite	14° 3′.
Schcelite	16° 31′.

The form 1 ∞ $\frac{1}{3}$, $\frac{1}{3}$ P ∞ Naumann; 103 Miller; and b^3 Brooke and Levy.

Calomel	30° 9′.
Hausmannite	28° 58′.
Wulfenite	27° 40′.

Hausmannite cleaves parallel to this form.

The form 1 ∞ $\frac{1}{2}$, $\frac{1}{2}$ P ∞ Naumann; 102 Miller; b^2 Brooke and Levy.

Apophyllite	32° 2′.
Edingtonite	25° 26′.
Scheelite	36° 34′.
Torberite	32° 4′.
Wulfenite	38° 11′.

The form 1 ∞ $\frac{2}{3}$, $\frac{2}{3}$ P ∞ Naumann; 203 Miller; $b^{\frac{3}{2}}$ Brooke and Levy.

Torberite	39° 53′.
Towanite	33° 18′.
Wulfenite	46° 21′.

The form 1 ∞ $\frac{3}{2}$, $\frac{3}{2}$ P ∞ Naumann; 302 Miller; $b^{\frac{2}{3}}$ Brooke and Levy.

Towanite	55° 55′.
Wulfenite	67° 2′.

The form 1 ∞ 2, 2 P ∞ Naumann; 201 Miller; $b^{\frac{1}{2}}$ Brooke and Levy.

Anatase	74° 14′.
Braunite	70° 15′.
Idocrase	46° 57′.
Torberite	68° 15′.
Towanite	63° 6′.

Torberite cleaves perfectly parallel to this form.

The form $1\,\infty\,3$, $3\,P\,\infty$ Naumann; 301 Miller; $b^{\frac{1}{3}}$ Brooke and Levy.

Rutile	62° 38′.
Tin	49° 10′.

The form $1\,\infty\,5$, $5\,P\,\infty$ Naumann; 501 Miller; $b^{\frac{1}{5}}$ Brooke and Levy.

Cassiterite	73° 26′.

When m becomes infinitely great this pyramid passes into the square prism whose sign is $1\,\infty\,\infty$; as m approaches to zero the pyramid approximates to the basal pinacoid.

Double Four-faced Pyramids derived from the Pyramid of the Second Order.—Retaining the same base $M_1\,M_2\,M_3\,M_4$, as in Fig. 196. Take $C\,P_3$, $C\,P_6$, as in Fig. 201, equal to m times $C\,P_1$, Fig. 196, m being any fraction or whole number greater than unity.

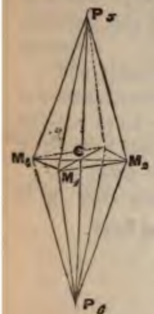


Fig. 201.

Join $P_3\,M_1$, $P_3\,M_2$, &c., as in Fig. 201.

For Fig. 201 take $C\,P_5$, or $C\,P_4$ equal to m times $C\,P_1$ (Fig. 196), m being less than unity.

Join $P_5\,M_1$, $P_5\,M_2$, &c., as in Fig. 202, and the pyramid will be constructed.

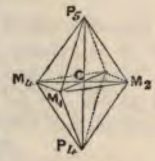


Fig. 202.

The series of pyramids, such as Fig. 201, are more acute, and those described as Fig. 202 are more obtuse than the original pyramid whose symbol is 1 1 1.

Symbols.—The symbol for these pyramids whose faces cut two of the axes at a distance equal to that of the equal parameters from their centre, and the third at a distance m times the greater paramenter, is 11 m. Naumann's symbol is mP, Miller's hhl, Brooke and Levy's $a^{\frac{1}{m}}$.

Poles.—The poles of these pyramids always lie in the zone $d\,P\,d$ (Fig. 195), those of the acute pyramids being between b and d, those of the acute being between P and b.

Axes.—The axes join the opposite four-faced solid angles.

Inclination of Faces.—If ϕ be the angle of inclination of adjacent faces over the edges $M_1\,M_2$, $M_2\,M_3$, &c. (Figs. 201 and 202), θ that over the edges $P_5\,M_1$, $P_5\,M_2$, &c., α the angular element of the substance,

$$\tan.\ \frac{\pi - \phi}{2} = \frac{1}{m}\ \cot.\ \alpha\ \cos.\ 45^\circ.$$

$$\cos.\ (\pi - \theta) = \left(\sin.\ \frac{\pi - \phi}{2}\right)^2$$

Forms of the Double four-faced Pyramid, whose Symbol is 11 m, *which have been observed in Nature, together with the Latitude of their Poles on the Sphere of Projection.*

The form 1, 1, $\frac{1}{16}$; $\frac{1}{16}$ P Naumann; 1, 1, 16 Miller; a^{16} Brooke and Levy.

Wulfenite	7° 55′.

The form 1, 1, $\frac{1}{7}$; $\frac{1}{7}$ P Naumann; 1, 1, 7 Miller; a^{7} Brooke and Levy.

Anatase	19° 45′.

The form 1, 1, $\frac{1}{5}$; $\frac{1}{5}$ P Naumann; 1, 1, 5 Miller; a^5 Brooke and Levy.

Anatase	26° 14′.
Apophyllite	19° 30′.

The form 1, 1, $\frac{2}{9}$; $\frac{2}{9}$ P Naumann; 2, 2, 9 Miller; $a^{\frac{9}{2}}$ Brooke and Levy.

Wulfenite	26° 18′.

The form 1, 1, $\frac{1}{4}$; $\frac{1}{4}$ P Naumann; 1, 1, 4 Miller; a^4 Brooke and Levy.

Towanite	19° 23′.

The form 1, 1, $\frac{1}{3}$; $\frac{1}{3}$ P Naumann; 1, 1, 3 Miller; a^3 Brooke and Levy.

Anatase	30° 38′.
Idocrase	14° 10′.
Towanite	24° 55′.
Apophyllite	30° 32′.
Sarcolite	22° 41′.
Wulfenite	36° 33′.
Calomel	39° 24′.
Scheelite	34° 58′.

Wulfenite cleaves parallel to this pyramid.

The form 1, 1, $\frac{1}{2}$; $\frac{1}{2}$ P Naumann; 1, 1, 2 Miller; a^2 Brooke and Levy.

Idocrase	20° 44′.
Scheelite	46° 22′.
Stolzite	47° 55′.
Towanite	34° 52′.

The form 1, 1, $\frac{3}{5}$; $\frac{3}{5}$ P Naumann; 3, 3, 5 Miller; $a^{\frac{5}{3}}$ Brooke and Levy.

Cassiterite	29° 43′.

The form 1, 1, $\frac{3}{2}$; $\frac{3}{2}$ P Naumann; 3, 3, 2 Miller; $a^{\frac{2}{3}}$ Brooke and Levy.

Towanite	64° 26′.
Wulfenite	73° 19′.

The form 1, 1, 2; 2 P Naumann; 2, 2, 1 Miller; $a^{\frac{1}{2}}$ Brooke and Levy.

Idocrase	56° 33′.
Stolzite	77° 17′.
Towanite	70° 16′.
Zircon	61° 6′.

The form 1, 1, $\frac{5}{2}$; $\frac{5}{2}$ P Naumann; 5, 5, 2 Miller; $a^{\frac{2}{5}}$ Brooke and Levy.

Cassiterite	67° 21′.

The form 1, 1, 3; 3 P Naumann; 3, 3, 1 Miller; $a^{\frac{1}{3}}$ Brooke and Levy.

Idocrase	66° 34′.
Scapolite	61° 50′.
Tin	58° 34′.
Zircon	69° 48′.

The form 1, 1, 4; 4 P Naumann; 4, 4, 1 Miller; $a^{\frac{1}{4}}$ Brooke and Levy.

Idocrase	71° 43′.

As *m* increases in magnitude, this pyramid approaches to the square prism whose *symbol is 1 1 ∞;* and when *m* becomes infinite coincides with it.

Sphenoid derived from the Pyramid of the First Order.—By developing half the faces of the double four-faced pyramid of the first order, a hemihedral form, with inclined faces is produced, which is called a *sphenoid*, or *irregular tetrahedron*. Thus (Fig. 203), the four-faces $P_1\,G_1\,G_4$, $P_1\,G_2\,G_3$, $P_2\,G_1\,G_2$, and $P_2\,G_3\,G_4$ of the pyramid $P_1\,G_1\,G_2\,P_2$ (Fig. 189) being produced till they meet, form the sphenoid $Q_1\,Q_2\,Q_3\,Q_4$ (Fig. 203). This sphenoid may be called the *positive sphenoid*. The other four faces being produced till they meet, form another sphenoid equal in all respects to the former, and differing only in position; this is called the *negative sphenoid*.

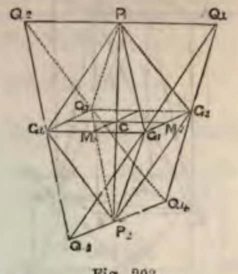


Fig. 203.

The *sphenoid*, so called from its wedge-like shape, is bounded by four isosceles triangles, such as $Q_1\,Q_2\,Q_3$; has six equal edges, such as $Q_1\,Q_2$; and four three-faced solid angles Q_1, Q_2, Q_3 and Q_4.

To Draw the Sphenoid derived from the Pyramid of the First Order.—Through P_1 (Fig. 203) draw $Q_1\,Q_2$ parallel to $G_1\,G_4$; and through P_2, $Q_3\,Q_4$ parallel to $G_1\,G_2$. Make $P_1\,Q_1$ and $P_1\,Q_2$ equal to $G_1\,G_4$, and $P_2\,Q_4$ and $P_2\,Q_3$ equal to $G_1\,G_2$. Join $Q_1\,Q_3$, $Q_1\,Q_4$, $Q_2\,Q_3$, and $Q_2\,Q_4$. In a similar manner the sphenoids, derived from the double four-faced pyramids (Figs. 199 and 200), may be drawn.

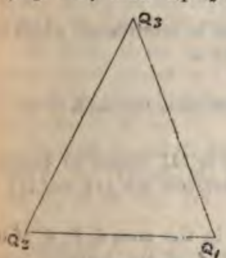


Fig. 204.

To Construct the Net for the Sphenoid.—Draw the line $Q_1\,Q_2$ (Fig. 204) equal to twice $G_1\,G_2$ (Fig. 193); on it describe the isosceles triangle $Q_1\,Q_3\,Q_2$, having each of its sides, $Q_1\,Q_3$, $Q_2\,Q_3$, equal twice $P\,G_1$ (Fig. 192). $Q_1\,Q_2\,Q_3$ will be a face of the sphenoid; and four such faces, arranged as in Fig. 205, will form the required net.

Fig. 205.

Crystals whose Faces occur parallel to the Sphenoid derived from the Pyramids of the First Order.

The sphenoid, derived from the pyramid whose symbol is 11∞, occurs in Edingtonite, Stobzite, Towanite, and Wulfenite; and from the pyramid whose sign is $1\infty\frac{1}{2}$ in Edingtonite.

The poles $a_1\,a_3$ of the *positive sphenoid* lie in the zone $M_1\,P_1\,M_4$ (Fig. 195), in the northern hemisphere of the sphere of projection; and the other two poles in the zone, $M_2\,P_2\,M_3$, in the southern hemisphere: $a_2\,a_4$, poles of the *negative sphenoid*, lie in the zone $M_2\,P_1\,M_3$ of the northern hemisphere; the poles in the southern lie in the zone $M_1\,P_1\,M_2$.

Sphenoid derived from the Pyramid of the Second Order.—By developing, as in the last case, the alternate faces of the double four-faced pyramid (Fig. 197) whose symbol is 111, two hemihedral forms with inclined faces will be produced, which are sphenoids.

To Construct the Sphenoid.—Draw the prism $A_1\,A_2\,A_5\,A_7$ (Fig. 206) as in Fig. 196. Join $A_1\,A_3$, $A_6\,A_8$, $A_1\,A_5$, $A_7\,A_3$, $A_7\,A_8$, and $A_2\,A_6$, and the positive sphenoid $A_1\,A_3\,A_8\,A_6$

(Fig. 207) will be drawn. The *negative sphenoid* may be constructed by joining the points A_2 A_4, A_5 A_7, A_2 A_5, A_4 A_5, A_2 A_7, and A_4 A_8.

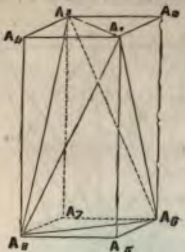


Fig. 206.

Fig. 207.

Fig. 208.

To Construct the Face of this Sphenoid.—Draw A_1 A_3 (Fig. 208) equal to twice M_1 M_2 (Fig. 198); on it describe the isosceles triangle A_1 A_8 A_3, having its sides A_1 A_8, and A_3 A_8, equal to twice P M_1 (Fig. 198). Four such triangles, arranged as in Fig. 205, will form the net for this sphenoid.

In a similar manner the sphenoids and their nets may be constructed, which are derived from the pyramids whose symbols are of the form 11 *m*.

Crystals whose Faces occur parallel to the Sphenoids derived from Pyramids of the Second Order.

The sphenoid derived from the pyramid whose symbol is 111 occurs in Stolzite, Towanite, and Wulfenite; and from the pyramids whose symbols are 11$\frac{1}{4}$ and 11$\frac{1}{2}$ in Towanite.

The poles b_1 b_2 (Fig. 195) of the *positive sphenoid* lie in the zone d_4 P_1 d_2 of the northern hemisphere; and its other poles in the zone d_3 P_1 d_1 of the southern hemisphere of the sphere of projection. The poles b_3 b_4 of the *negative sphenoid* lie in the zone d_1 P_1 d_3 of the northern, and its other poles in the zone d_4 P_1 d_2 of the southern hemisphere.

Octagonal Prism.—The *octagonal prism*, also called the *ditetragonal prism*, and the right prism on an octagonal base, is a solid bounded by ten faces, eight of which, such as M_1 E_1 E_5 M_5, are rectangular parallelograms, forming the sides of the prism. The other two, forming the top and bottom of the prism, are irregular octagons. When this prism is considered an open form, its sides alone are considered the planes of the prism, and the two faces which inclose it are the planes of the *basal pinacoids*.

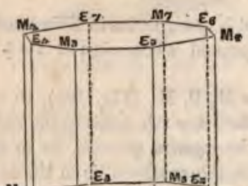


Fig. 209.

Axes.—The rectangular axes, in which the equal parameters are taken, join the points M_1 M_3, and M_2 M_4; while the third axis coincides with the geometrical axis of the prism.

Symbols.—Each face of the octagonal prism cuts one of the axes, as C M_1 (Fig. 190), at a distance C M_1 equal to the length of one of the equal parameters; the other axis, as C M_2, at a distance equal *n* times that parameter, where *n* may represent any whole number or fraction greater than unity, and the face is parallel to the third axis C P_1, in which the unequal parameter is taken.

The symbol which expresses this relation to the axes is $1\ n\ \infty$.

Naumann's symbol for this form is $\infty P n$, Miller's $h\ k\ o$, Brooke and Levy's g^n.

Inclination of the Faces.—Let ϕ be the angle of inclination of the faces measured over the edges $E_1\ E_5$, $E_2\ E_6$, &c., and θ over the edges $M_2\ M_6$, $M_3\ M_7$.

$$\text{Cos. } (\pi - \theta) = \frac{n^2 - 1}{n^2 + 1} \text{ or tan. } \left(\frac{\pi - \theta}{2}\right) = \frac{1}{n}, \text{ and } \phi = 270° - \theta.$$

To Draw the Octagonal Prism.—Describe a square, $G_1\ G_2\ G_3\ G_4$ (Fig. 210) having each of its sides equal to twice the arbitrary unit chosen for the equal parameters of the system. Let C be the centre of the square, $M_1\ M_2\ M_3$ and M_4 the centres of its sides. Join $M_1\ M_3$ and $M_2\ M_4$, $G_2\ G_4$, and $G_1\ G_3$.

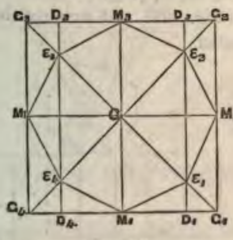


Fig. 210.

Let $M_1\ E_1$ be a line drawn from M_1 to meet C M_2, produced in a point at a distance equal to n times C M_2 from C; and let E_1 be the point where this line cuts C G_1. Take C E_2, C E_3, and C E_4, each equal to C E_1. Join $E_1\ M_2$, $M_2\ E_2$, $E_2\ M_3$, $M_3\ E_3$, &c. Through E_1 and E_4 draw $D_1\ D_2$, and $D_4\ D_3$, parallel to $G_1\ G_2$.

$M_1\ E_1\ M_2\ E_2$ &c. E_4, is the octagonal base of the prism whose symbol is $1\ n\ \infty$. To draw the prism, draw $G_1\ G_4$ (Fig. 214); make $G_1\ G_4$ equal $G_1\ G_4$ (Fig. 210), and divide it similarly in the points $D_1\ M_1$ and D_4.

Through G_1 and G_4 draw $G_1\ G_2$, and $G_4\ G_3$ (Fig. 214), making an angle of about 30° with $G_1\ G_4$. Take $G_4\ M_4$, $G_3\ M_2$, $M_4\ G_3$, and $M_2\ G_1$, equal to half $G_4\ M_4$, $G_3\ M_2$, $M_4\ G_3$, and $M_2\ G_1$ of Fig. 210. Through D_4 and D_1 draw $D_4\ D_3$, and $D_1\ D_2$, parallel to $G_1\ G_2$.

Take $D_1\ E_1$, $D_1\ E_2$, $D_4\ E_4$, and $D_4\ E_3$, equal to half $D_1\ E_1$, $D_1\ E_2$, $D_4\ E_4$, and $D_4\ E_2$ (Fig. 209). Join $M_1\ E_1$, $E_1\ M_2$, &c. Then $M_1\ E_1$ &c. $M_4\ E_4$ (Figs. 214 and 209) will be a perspective representation of the octagonal base of the prism.

Through M_1 draw $M_1\ M_5$ (Fig. 209), perpendicular to $M_1\ E_1$, and of any height. Through E_1, M_2, E_3, M_3, &c., draw $E_1\ E_5$, $M_2\ M_6$, $E_2\ E_6$, $M_3\ M_7$, &c., parallel and equal to $M_1\ M_5$. Join $E_5\ M_6$, $M_6\ E_6$, &c., and Fig. 209 will be the representation of the octagonal prism in isometrical perspective.

Position of the poles of the Faces of the Octagonal Prism on the sphere of projection.— The poles of the faces of the octagonal prism always lie in the same zone, and that zone is the equator of the sphere of projection; $c_1\ c_2$, &c., c_8 (Fig. 195) represent these poles, each situated at the same angular distance from the points M_1, M_2, M_3, and M_4. The angle θ, given above, is this angular distance, and is the longitude of the pole reckoning from M_1.

Forms of the Octagonal Prism, parallel to which faces have been observed in nature, together with the longitude of their poles on the sphere of projection.

The form $1\ \frac{3}{2}\ \infty$, $\infty P\ \frac{3}{2}$ Naumann; 230 Miller; and $g^{\frac{3}{2}}$ Brooke and Levy, whose longitude is 33° 41′, occurs in crystals of Cassiterite, Fergusonite, Rutile, and Wulfenite.

The form $1\ 2\ \infty$, $\infty P\ 2$ Naumann; 210 Miller; and g^2 Brooke and Levy, longitude

Every face of this pyramid cuts one of the axes, such as $M_1 M_3$, at a distance equal to the arbitrary unit, the second $M_2 M_4$ at a distance n times that unit, n being any whole number or fraction greater than unity, and the third axis $C P_1$ at a distance m times that of the unequal parameter, m being any whole number or fraction greater or less than unity.

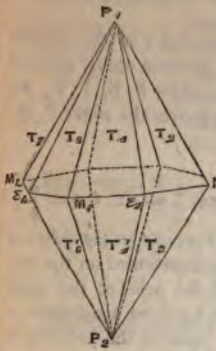


Fig. 213.

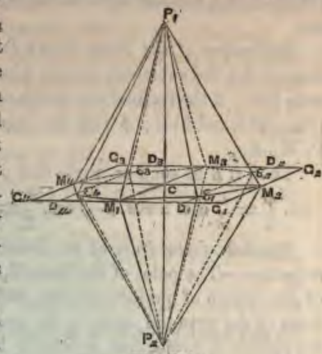


Fig. 214.

The symbol which expresses this relation of the figure to the axes of the pyramidal system, is $1\,m\,n$; Naumann's symbol is $m\,P\,n$; Miller's $h\,k\,l$; and Brooke and Levy's $b^{\frac{1}{h}}\ b^{\frac{1}{k}}\ g^{\frac{1}{l}}$.

To draw the Double Eight-faced Pyramid.—The same construction being made for the base of the pyramid (Fig. 210), as for the base of the octagonal prism whose symbol is $\infty P\,n$, this base is to be drawn in perspective (Fig. 214), in the manner in which the base of the octagonal prism was directed to be drawn. Through C draw $P_1 C P_2$ perpendicular to $M_2 M_4$, take $C P_1$ and $C P_2$ equal to m times the unequal parameter.

Join $P_1 M_1$, $P_1 E_1$, $P_1 E_2$, $P_1 M_2$, &c., $P_2 M_1$, $P_2 E_1$, &c., and the pyramid will be constructed.

To describe a Net for the Double Eight-faced Pyramid.—Draw C N (Fig. 215), equal to C N (Fig. 211), and C P perpendicular to C N. Make C P equal to m times the unequal parameter, the length of this parameter being determined by the method given in page 361, Fig. 186. Join P N.

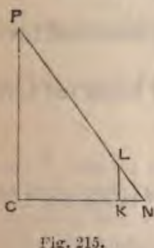


Fig. 215.

Fig. 216.

Fig. 217.

Then Fig. 216.—Draw $N_1 N_2$ equal $N_1 N_2$ (Fig. 212), and take in it the points E_1 and M_2, at the same distances from N_1 and N_2 they are in Fig. 212.

On $N_1 N_2$ describe an isosceles triangle, $P N_1 N_2$, having its sides, $P N_1$ and $P N_2$, equal to P N (Fig. 215). Join $P E_1$ and $P M_2$.

$P E_1 M_2$ will be the scalene triangle which will be a face of the double eight-faced pyramid, and sixteen such triangles, arranged as in Fig. 217, will form the required net.

Inclination of the Faces of the Double Eight-faced Pyramid.—Let a be the angular element for the substance among whose crystals faces of this pyramid occur, given in page 360. θ the inclination of adjacent faces, measured over the edges $P_1 E_1$, $P_1 E_2$, &c. (Figs. 212 and 213); ϕ over the edges $E_1 M_1$, $E_1 M_2$, &c.; and ψ over the edges $P_1 M_1$, $P_1 M_2$, &c.

Then if β be such an angle that cot. $\beta = n$,

$$\cot. \frac{\phi}{2} = \frac{1}{m} \cot. a \cos. \beta \quad \cos. \frac{\theta}{2} = \sin. \frac{\phi}{2} \cos. (45^\circ + \beta) \quad \cos. \frac{\psi}{2} = \sin. \beta \sin. \frac{\phi}{2}.$$

Position of the Poles of the Faces of the Double Eight-faced Pyramid on the sphere of projection.—The poles of the faces T_1 T_2, &c., T_8 (Fig. 213); are represented on the map of the sphere of projection (Fig. 195), by T_1 T_2, &c., T_8. All the poles of the upper faces of the pyramid occur in the same circle of latitude in the northern hemisphere of the sphere of projection, reckoning the latitude from P_1, and those of the lower faces of the pyramid in the same circle of south latitude, reckoning from P_2.

The angle $\frac{\phi}{2}$ in the preceding article will be the angle of latitude for the faces of the pyramid; and β will be the longitude of T_1, reckoning the longitude from $P_1 M_1$ as the first meridian of longitude.

The longitude of T_2 will be $90^\circ - \beta$, of T_3 $90^\circ + \beta$, of T_4 $180^\circ - \beta$, east of M_1, while the longitude of T_8, T_7, T_6, and T_5 will be the same angles west of M_1.

Crystals whose Faces occur parallel to the Double Eight-faced Pyramid, together with their Latitude and Longitude on the sphere of projection.

The form 1, 5, $\frac{5}{19}$; $\frac{5}{19}$ P 5 Naumann; 5, 1, 19 Miller; and $b^1 b^{\frac{1}{5}} g^{\frac{1}{19}}$ Brooke and Levy.

Anatase, Lat. 25° 30′. Lon. 11° 18.

The form 1, 3, $\frac{1}{2}$; $\frac{1}{2}$ P 3 Naumann; 3, 1, 6 Miller; and $b^1 b^{\frac{1}{3}} g^{\frac{1}{6}}$ Brooke and Levy.

Towanite, Lat. 27° 27′. Lon. 18° 26′.

The form 1, 2, 1; P 2 Naumann; 2, 1, 2 Miller; and $b^1 b^{\frac{1}{2}} g^{\frac{1}{2}}$ Brooke and Levy.

Scheelite, Lat. 58° 55′. Lon. 26° 34′.

The form 1, 3, 1; P 3 Naumann; 3, 1, 3 Miller; and $b^1 b^{\frac{1}{3}} g^{\frac{1}{3}}$ Brooke and Levy.

Cassiterite, Lat. 35° 20′. Lon. 18° 26′.
Rutile Lat. 34° 11′. Lon. 18° 26′.
Sarcolite, Lat. 43° 5′ Lon. 18° 26′.

The form 1, 3, $\frac{3}{2}$; $\frac{3}{2}$ P 3 Naumann; 3, 1, 2 Miller; $b^1 b^{\frac{1}{3}} g^{\frac{1}{2}}$ Brooke and Levy.

Idocrase, Lat. 40° 41′. Lon. 18° 26′.

The form 1, 2, 2; 2 P 2 Naumann; 2, 1, 1 Miller; $b^1 b^{\frac{1}{2}} g^1$ Brooke and Levy.

Idocrase, Lat. 50° 7′. Lon. 26° 34′.
Phosgenite, Lat. 67° 36′. Lon. 26° 34′.

The form 1, $\frac{3}{2}$, 3; 3 P $\frac{3}{2}$ Naumann; 3, 2, 1 Miller; $b^{\frac{1}{2}} b^{\frac{1}{3}} g^1$ Brooke and Levy.

Cassiterite, Lat. 67° 35′. Lon. 33° 41′.
Fergusonite, Lat. 79° 17′. Lon. 33° 41′.
Rutile, Lat. 66° 42′. Lon. 33° 41′.

The form 1, 3, 3; 3 P 3 Naumann; 3, 1, 1 Miller; $b^1\, b^{\frac{1}{3}}\, g^1$, Brooke and Levy.

Braunite,	Lat. 77° 13′.	Lon. 18° 26′.
Idocrase,	Lat. 59° 25′.	Lon. 18° 26′.
Sarcolite,	Lat. 70° 23′.	Lon. 18° 26′.
Scapolite,	Lat. 54° 18′.	Lon. 18° 26′.
Scheelite,	Lat. 77° 58′.	Lon. 18° 26′.
Zircon,	Lat. 63° 52′.	Lon. 18° 26′.

The form 1, 2, 4; 4 P 2 Naumann; 4, 2, 1 Miller; $b^{\frac{1}{2}}\, b^{\frac{1}{4}}\, g^1$ Brooke and Levy.

Idocrase,	Lat. 67° 20′.	Lon. 26° 34′.

The form 1, 4, 4; 4 P 4 Naumann; 4, 1, 1 Miller; $b^1\, b^{\frac{1}{4}}\, g^1$ Brooke and Levy.

Idocrase,	Lat. 65° 37′.	Lon. 14° 2′.
Zircon,	Lat. 69° 23′.	Lon. 14° 2′.

The form 1, 5, 5; 5 P 5 Naumann; 5, 1, 1 Miller; $b^1\, b^{\frac{1}{5}}\, g^1$ Brooke and Levy.

Idocrase,	Lat. 69° 53′.	Lon. 11° 18′.
Towanite,	Lat. 78° 44′.	Lon. 11° 18′.
Zircon,	Lat. 73° 0′.	Lon. 11° 18′.

Hemihedral Double Four-faced Pyramid.—If we represent the eight upper faces of the *double eight-faced pyramid* (Fig. 213) by the symbols T_1, T_2, T_3, T_4, T_5, T_6,

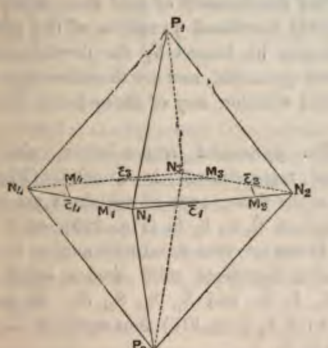


Fig. 218.

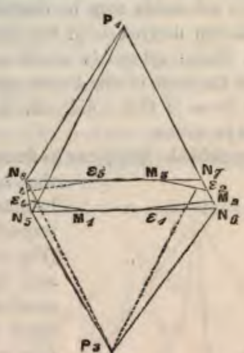


Fig. 219.

T_7 and T_8, and the corresponding lower faces by T'_1, T'_2, T'_3, T'_4, T'_5, T'_6, T'_7, and T'_8. Then if the eight faces T_1, T'_1, T_3, T'_3, T_5, T'_5, T_7, and T'_7, be produced till they meet, the resulting form will be the *double four-faced pyramid* $P_1\, N_5\, N_6\, P_2$, &c. (Fig. 219). If the other eight faces of the *double eight-faced pyramid*, T_2, T'_2, T_4, T'_4, T_6, T'_6, T_8, and T'_8 be produced to meet, they will form the *double four-faced pyramid*. $P_1\, N_1\, N_2\, P_2$, &c. (Fig. 218.)

These pyramids are equal to each other in every respect, and differ only in their situation with regard to the axes of the pyramidal system. They are the *positive and negative hemihedral forms with parallel faces* of the double eight-faced pyramid.

The axis in which the unequal parameters are taken join the apices P_1 and P_2 in both pyramids. The position in which the other two axes cut the bases of these pyramids will be seen by referring to Fig. 212, where the lines $N_1 N_2$, $N_2 N_3$, $N_3 N_4$, and $N_4 N_1$, forming the square $N_1 N_2 N_3 N_4$, formed by producing the edges $E_1 M_2$, $E_2 M_3$, $E_3 M_4$, and $E_4 M_1$ of the base of the double eight-faced pyramid, is the base of the pyramid Fig. 218; and the square $N_5 N_6 N_7 N_8$ formed by the other edges of the base of the double eight-faced pyramid, is the base of the pyramid Fig. 219.

$M_1 M_3$ and $M_2 M_4$ will be the axes in both pyramids.

To draw the Hemihedral Double Four-faced Pyramids.—Draw the double eight-faced pyramid as described for the construction of Fig. 214. Produce $E_1 M_2$, $E_2 M_3$, $E_3 M_4$, and $E_4 M_1$ (Fig. 218), to meet in the points $N_1 N_2 N_3$ and N_4. Join $P_1 N_1$, $P_1 N_2$, &c., $P_2 N_1$, $P_2 N_2$, &c., and Fig. 218 will be constructed.

Produce $M_1 E_1$, $M_2 E_2$, $M_3 E_3$ and $M_4 E_4$ to meet in $N_5 N_6 N_7$ and N_8, and join these points with P_1 and P_2, and Fig. 219 will be constructed.

To Construct a Net for the Hemihedral Double Four-faced Pyramid.—The isosceles triangle $P N_1 N_2$ (Fig. 216) is a face of the double four-faced pyramid derived from the double eight-faced pyramid whose face is $P E_1 M_2$; and eight of these triangles, arranged as in Fig. 194, will form the required net.

Faces Parallel to the Hemihedral Double Four-faced Pyramid which occur in Nature.

In Scheelite from the pyramids 1, 2, 1, and 1, 2, 3. Sarcolite from the pyramid 1, 3, 1, and Fergusonite from the pyramid 1, $\frac{3}{2}$, 3.

Tetartohedral Form.—From each of the hemihedral double four-faced pyramids, two sphenoids may be derived by the development of half their faces, just as sphenoids are derived from the other double four-faced pyramids of the pyramidal system. These sphenoids would consequently be formed by the development of a fourth of the faces of the double eight-faced pyramids,, and are therefore called *tetartohedral forms* of that solid. It is doubtful whether any of these forms have been observed in nature.

Pyramidal Trapezohedron. — The *pyramidal trapezohedron*, also called the *tetragonal trapezohedron*, is a solid (Fig. 220), bounded by eight faces, each of which is an irregular trapezium, such as $P_1 L_1 S_1 L_2$ (Fig. 220), or $P L_1 S L_2$ (Fig. 216). It has two four-faced solid angles, P_1 and P_2, and eight more four-faced solid angles equal to one another $L_1 L_2 L_3 L_4$, and S_1, S_2, S_3, S_4. It has eight edges equal to $P L_1$ (Fig. 216) four equal to $L_1 S_1$, and four equal to $L_2 S_1$.

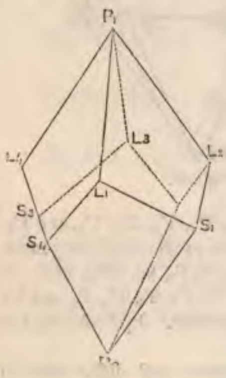


Fig. 220.

The pyramidal trapezohedron is a *hemihedral form, with inclined faces* of the double eight-faced pyramid, and is formed by producing the eight faces T_1, T'_2, T_3, T'_4, T_5, T'_6, T_7 and T'_8, to meet one another. A similar and equal trapezohedron would be formed by producing the faces T'_1, T_2, T'_3, T_4, T'_5, T_6, T'_7, and T_8 to meet.

This trapezohedron may also be regarded as formed by the combination of the upper half of a positive hemihedral four-faced pyramid, with the lower half of its corresponding negative hemihedral four-faced pyramid.

To Draw the Pyramidal Trapezohedron.—Draw the base of the double eight-faced pyramid $M_1 E_1$, $M_2 E_2$, &c. (Fig. 214), and its axis $P_1 P_2$ (Fig. 221). Produce $M_1 E_1$,

M_2 E_2, &c., to meet in N_5 N_6 N_7 and N_8, as in Fig. 212; and E_1 M_2, M_2, E_2, &c., to meet in N_1 N_2 N_3 N_4.

Join N_1, N_2, N_3 and N_4 with P_1 and N_5, N_6, N_7 and N_8 with P_2.

Then (Fig. 212) join C N_1, cutting M_1 E_1 in K.

In Fig. 215, take C K equal to C K (Fig. 212), and through K draw K L perpendicular to C N, meeting P N in L.

In Fig 221 take C H_1 and C H_2 in P_1 P_2, equal to K L (Fig. 215).

Through H_1 draw L_1 L_3 parallel to N_1 N_3, meeting P_1 N_1 and P_1 N_3 in L_1 and L_3, and L_2 L_4 parallel to N_2 N_4, meeting P_1 N_2, and P_1 N_4, in L_2 and L_4.

Through H_2 draw S_1 S_3 parallel to N_6 N_8, and S_2 S_4 parallel to N_7 N_5.

Join L_1 S_1 L_2, L_2 S_2 L_3, &c., as in Fig. 220, and the trapezohedron will be constructed.

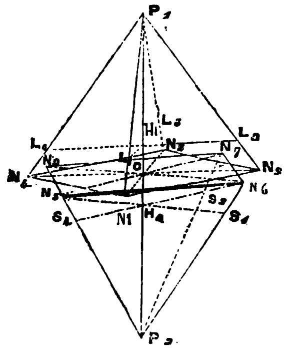


Fig. 221.

To Describe a Net for the Pyramidal Trapezohedron.—In Fig. 216, take P L_1 and and P L_2 in P N_1 and P N_2, equal to P L, Fig. 215.

Join L_1 E_1 and L_2 M_2, and produce these lines to meet in S.

P L_1 S L_2 will be a face of the trapezohedron; and eight such faces, arranged as in Fig. 222, will form the required net.

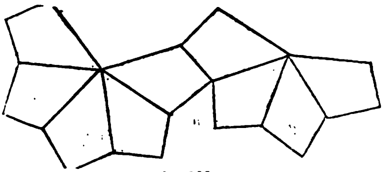


Fig. 222.

Faces parallel to the Pyramidal Trapezohedron which occur in Nature.—Faces parallel to the pyramidal trapezohedron have only been observed in crystals of Scapolite, derived from the double eight-faced pyramid whose symbol is 133.

Pyramidal Scalenohedron.—The *pyramidal scalenohedron*, also called the *tetragonal scalenohedron*, and by some the *diplo-tetrahedron*, is a solid bounded by eight faces, each of which, such as P_1 K_1 K_3 (Fig. 223), is a scalene triangle.

This is a *hemihedral form, with inclined faces*, of the double eight-faced pyramid, and is derived from it by producing the faces T_8, T_1, T'_2, T'_3, T_4, T_5, T' and T' (Fig. 213), to meet one another. Another scalenohedron, equal in all respects to this one, but differing in position, will be formed by producing T'_8, T'_1, T_2, T_3, T'_4, T'_5, T_6 and T_7. One of these may be called the positive and the other the negative scalenohedron.

This form has two four-faced solid angles P_1 and P_2, equal to each other; and four others, K_1 K_2 K_3 and K_4, equal to each other.

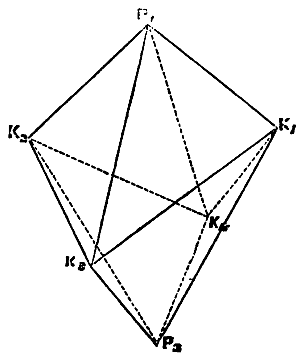


Fig. 223.

To draw the Pyramidal Scalenohedron.—Draw the base of the double eight-faced pyramid M_1 E_1 M_2, &c. (Fig. 224), as described for Fig. 214, as well as its axis P_1 P_2

Produce $M_1\,E_1$ and $M_3\,E_2$ to meet in R_1, $M_1\,E_4$ and $M_3\,E_3$ to meet in R_2, also $M_2\,E_1$ $M_4\,E_4$ to meet in R_3, and $M_2\,E_2$ and $M_4\,E_3$ to meet in R_4.

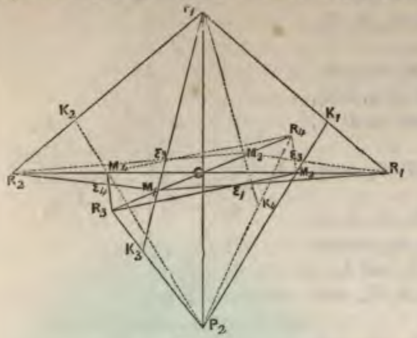


Fig. 224.

Join $P_1\,M_1$ and produce it to meet $P_2\,R_3$ in K_3, $P_2\,M_2$ to meet $P_1\,R_1$ in K_1, $P_1\,M_3$ to meet $P_2\,R_4$ in K_4, and $P_2\,M_4$ to meet $P_1\,R_2$ in K_2.

Join $K_1\,K_4$, $K_4\,K_2$, $K_2\,K_3$, and $K_3\,K_1$, as in Fig. 223, and the scalenohedron will be constructed.

To describe a Net for the Pyramidal Scalenohedron.—Draw a line $C\,P_1$ (Fig. 225), perpendicnlar to the line $C\,R_3$. Take $C\,P_1$ equal to $C\,P$ (Fig. 215), and $C\,M_1$ equal $C\,M_1$ (Fig. 212). Make $C\,R_2$ equal m, times $C\,M_1$; $1\,m\,n$ being the symbol of the double eight-faced pyramid, from which the scalenohedron is to be derived.

In $C\,P_1$ take $C\,M_2$ equal $C\,M_1$. Join $P\,M_1$ and $M_2\,R_2$.

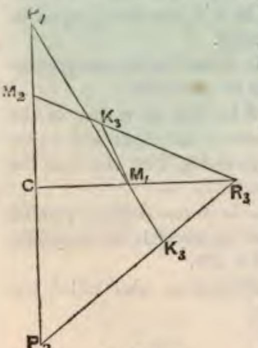


Fig. 225.

In $M_2\,R_2$ take $M_2\,K_3$ equal $M_2\,E_1$ (Fig. 212). Join $M_1\,K_3$.

Produce $P_1\,C$ to P_2, and make $C\,P_2$ equal to $C\,P_1$. Join $P_2\,R_2$, and produce $P_1\,M_1$ to meet $P_2\,R_3$ in K_2.

Then Fig. 226.—Draw the line $M_2\,R_3$ equal to $M_2\,R_2$ (Fig. 225), and on this as a base describe the triangle $M_2\,P\,R_3$, having its side $M_2\,P$ equal $M_1\,P_1$ (Fig. 225), and its side $P\,R_3$ equal to $R_2\,P_2$ (Fig. 225).

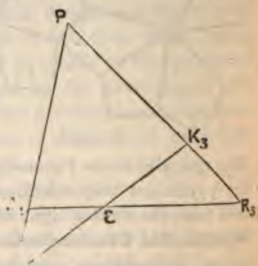


Fig. 226.

In $M_2\,R_3$ take $M_2\,E$ equal $M_2\,K_3$ (Fig. 225), and in $R_3\,P$, $R_3\,K_3$ equal to $R_2\,K_2$ (Fig. 225).

Join $K_3\,E$, and produce it to meet $P\,M_1$ produced in K_1. $P\,K_1\,K_3$ will be a face of the required scalenohedron; and eight such faces, arranged as in Fig. 227, will form the net for the scalenohedron.

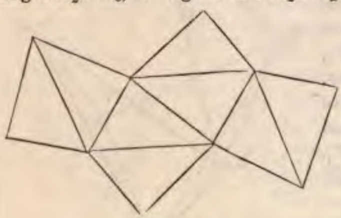


Fig. 227.

Faces parallel to the Pyramidal Scalenohedron which occur in Nature.

Faces parallel to this form have only been observed in crystals of Towanite or pyramidal copper pyrites, derived from the two double eight-faced pyramids whose symbols are 1, 3, $\frac{1}{2}$, and 1, 5, 5.

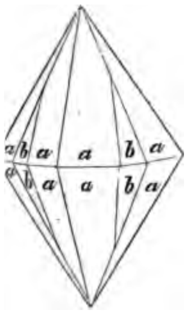


Fig. 228.

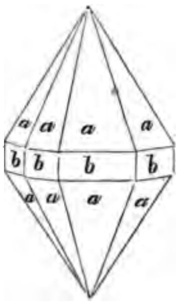


Fig. 229.

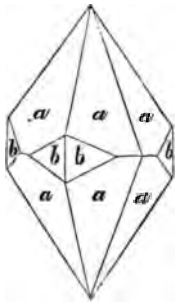


Fig. 230.

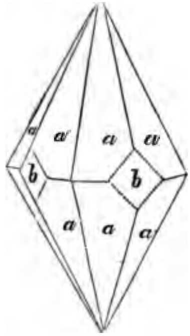


Fig. 231.

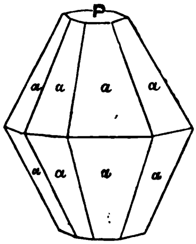


Fig. 232.

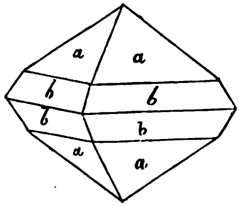


Fig. 233.

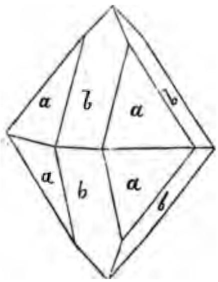


Fig. 234.

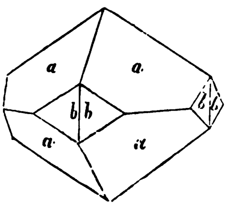


Fig. 235.

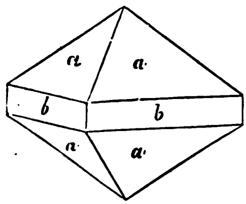


Fig. 236.

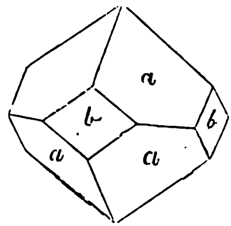


Fig. 237.

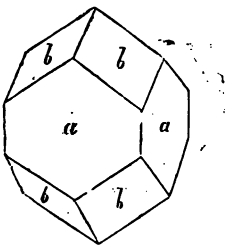


Fig. 238.

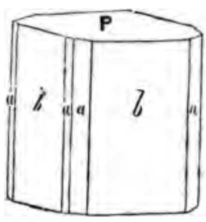


Fig. 239.

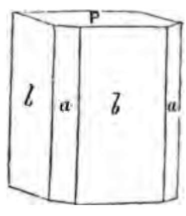


Fig. 240.

Principal combinations of the Pyramidal System.—A diligent study of the figures of these combinations, as already given, will enable us to read most, if not all, of the more complex combinations of this system. It is impossible, consistently with the limited space of an elementary work, to give all these combinations; but we hope those we have given will be quite sufficient for the purposes of the student.

Fig. 228. The *double eight-faced pyramid*, *a a a*, &c., whose symbol is 1 *n m*, with the alternate four-faced angles at its base replaced by faces *b b*, &c., of the *four-faced pyramid* whose symbol is 11 *m′*.

Fig. 229. The *double eight-faced pyramid*, *a a a*, &c., whose symbol is 1 *n m*, with the edges of its base replaced by faces *b b*, &c., of the *octagonal prism* whose symbol is 1, *n*, ∞.

Fig. 230. The *double eight-faced pyramid*, *a a a*, &c., whose symbol is 1 *n m*, with the alternate four-faced solid angles of its base replaced by two faces, *b b*, &c., of the *octagonal prism* whose symbol is 1, *n′*, ∞.

Fig. 231. The *double eight-faced pyramid*, *a a a*, &c.,whose symbol is 1 *n m*, with the alternate four-faced solid angles of its base replaced by faces *b b*, &c., of the *square prism* whose symbol is 1 1 ∞.

Fig. 232. The *double eight-faced pyramid*, *a a a*, &c., with its eight-faced solid angles replaced by planes P P of the *basal pinacoid* whose symbol is ∞ ∞ 1.

Fig. 233. The *double four-faced pyramid*, *a a a*, &c., whose symbol is 111, with the edges at its base replaced by faces *b b*, &c., of the *double four-faced pyramid* whose symbol is 1 1 *m*.

Fig. 234. The *double four-faced pyramid*, *a a a*, &c., whose symbol is 1 1 1, with its edges replaced by faces *b b*, &c., of the *double four-faced pyramid* 1 ∞ 1.

Fig. 235. The *double four-faced pyramid*, *a a a*, &c., whose symbol is 1 1 1, with the four-faced angles at its base replaced by two planes of the *octagonal prism* 1 *n* ∞.

Fig. 236. The *double four-faced pyramid*, *a a a*, &c., whose symbol is 1 1 1, with the edges at its base replaced by faces *b b*, &c., of the *square prism* 1 1 ∞.

Fig. 237. The *double four-faced pyramid*, *a a a*, &c., whose symbol is 1 1 1, with the four-faced angles at its base replaced by faces *b b*, &c., of the square prism 1 ∞ ∞.

Fig. 238. The *square prism*, *a a a*, &c., whose symbol is 1 ∞ ∞, inclosed by faces *b b*, &c., of the *double four-faced* pyramid 1 1 1.

Fig. 239. The *square prism*, *b b b*, &c., whose symbol is 1 1 ∞, with its edges replaced by planes *a a*, &c., of the *octagonal prism* 1 *n* ∞, and inclosed by the planes P, P of the *basal pinacoid*.

Fig. 240. The *square prism*, *b b b*, &c., whose symbol is 1 1 ∞, with its edges replaced by planes *a a*, &c., of the *square prism* 1 ∞ ∞, and enclosed by planes P, P of the *basal pinacoid*.

Fig. 241. The *positive sphenoid*, *a a*, &c., derived from the double four-faced pyramid 1 1 1, with its three-faced solid angles replaced by planes *b b*, &c , of the *negative sphenoid* derived from the same pyramid.

Fig. 242. The *positive sphenoid*, *a a*, &c., with its three-faced solid angles replaced by faces *b b*, &c., of the *square prism* 1 1 ∞.

Fig. 243. The *positive sphenoid*, *a a*, &c., with four of its edges replaced by faces *b b*, &c., of the *square prism* 1 ∞ ∞.

Fig. 244. The *double four-faced pyramid*, *a a*, &c., whose symbol is 1 ∞ 1, with four of its edges replaced by faces *b b*, &c., of the *sphenoid* derived from the *double four-faced pyramid* 1 1 *m*.

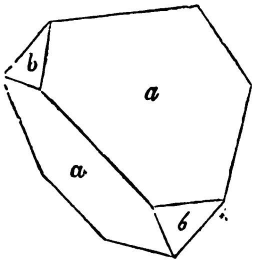


Fig. 241.

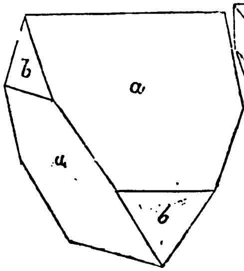


Fig. 242.

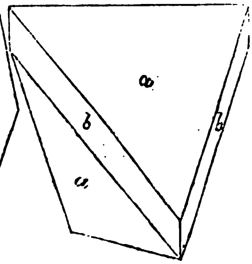


Fig. 243.

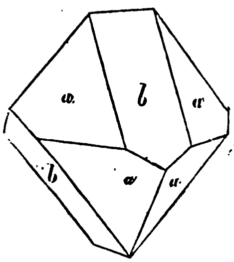


Fig. 244.

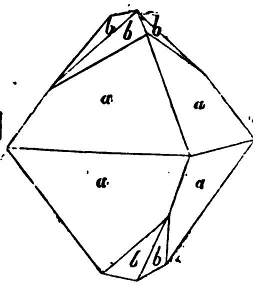


Fig. 245.

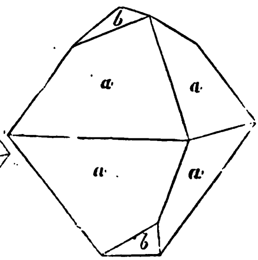


Fig. 246.

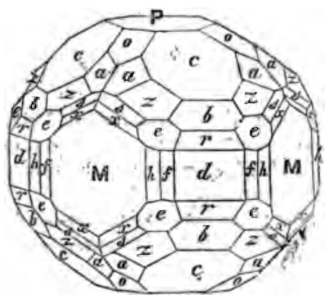


Fig. 247.

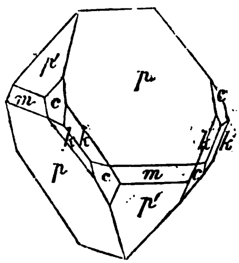


Fig. 248.

Fig. 245. The *double four-faced pyramid*, *a a*, &c., whose symbol is 1 ∞ 1, with the solid angles at its apices replaced by faces *b b*, &c., of the *scalenohedron*, derived from the *double eight-faced pyramid* 1 *n m*.

Fig. 246. The *double four-faced pyramid*, *a a*, &c., whose symbol is 1 ∞ 1, the solid angles at its apices replaced by faces *b b*, &c., of the *sphenoid* derived from the *double four-faced pyramid* 1 1 *m*.

Fig. 247. A complex holohedral combination of several forms of the pyramidal system in a crystal of Idocrase or pyramidal Garnet described by Mohs.

P, planes of the *basal pinacoid* ∞ ∞ 1.

Square prisms, M of the prism 1 ∞ ∞, *d* of the prism 1 1 ∞.

Octagonal prisms, *f* of the prism 1, 2, ∞ — *h* of the prism 1, 3, ∞.

Double four-faced pyramids, *o* of the pyramid 1 ∞ 1 — *c* of the pyramid 1, 1, 1 — *b* of the pyramid 1, 2, 1 — *r* of the pyramid 1, 4, 1.

Double eight-faced pyramids, *z* of the pyramid 1, 2, 2 — *s* of the pyramid 1, 3, 3 — *x* of the pyramid 1, 4, 4 — *e* of the pyramid 1, 2, 4 — *a* of the pyramid 1, 3, $\frac{3}{2}$.

Fig. 248. A complex hemihedral combination of forms of the pyramidal system in a crystal of Towanite or Pyramidal Copper Pyrites, described by Naumann, to whose works we take this opportunity of expressing our great obligation.

p, faces of the *positive sphenoid* derived from the four-faced pyramid 1 1 1.

p', faces of the *negative sphenoid* derived from the same pyramid.

k, faces of the *scalenohedron* derived from the double eight-faced pyramid 1 5 5.

c, faces of the *four-faced pyramid* 1, ∞, 2, and *m* those of the *square prism* 1 1 ∞.

THIRD SYSTEM—RHOMBOHEDRAL.

This system is called the *rhombohedral* when its forms are derived from the *rhomboid*; the *hexagonal* when derived from the regular *hexagonal prism*, or the *double pyramid on a hexagonal base*. It has also been called the *monotrimetrical* and *three-and-one axial*, from the properties of its axes.

The *holohedral forms* of this system are, two kinds of *right prisms on a regular hexagonal base*; two orders of *double six-faced pyramids* on regular hexagonal bases; the double *twelve-faced pyramid*; and *the right prism on a twelve-sided base*.

From each of these, by producing half their faces to meet one another, *hemihedral forms* are derived.

The hemihedral forms, with *inclined faces*, are the *triangular prism*, derived from the hexagonal prism; the double *three-faced pyramid*, derived from the double six-faced pyramid; the *double six-faced trapezohedron*, derived from the double twelve-faced pyramid.

The hemihedral forms, with *parallel faces*, are the *hexagonal prism*, derived from the twelve-faced prism; the *double six-faced pyramid*, from the double twelve-faced pyramid; the *rhomboid*, from the *double six-faced pyramid*; and the *hexagonal scalenohedron*, derived from the double twelve-faced pyramid.

The *tetartohedral* forms are the *triangular* prism from the twelve-faced prism; the *rhomboid*, *double three-faced pyramid*, and *double three-faced trapezohedron*,—all derived from the double twelve-faced pyramid.

Some of these forms are either so rare or so doubtful, that we shall confine our descriptions to the different kinds of prisms, the double six-faced pyramids, the rhomboid, and the scalenohedron.

Alphabetical List of Minerals belonging to the Rhombohedral System, together with the Angular Elements from which their Typical Form and Axes may be derived.

Alunite (Alum Stone)	52° 45′.
Ankerite	43° 54′.
Antimony	56° 28′.
Apatite (Phosphate of Lime)	55° 40′.
Arsenic	57° 51′.
Biotite (Mica)	70° 00′.
Bismuth	56° 24′.
Breithauptite (Nickel Antimonial) . . .	59° 47′.
Breunnerite	43° 8′.
Brucite	Unknown.
Calamine	42° 57′.
Calcite (Carbonate of Lime)	44° 37′.
Chabasie	50° 45′.
Chalybite (Carboniferous Oxide of Iron) . .	43° 23′.
Chlorite	66° 2′.
Clintonite	Unknown.
Cinnabar (Sulphuret of Mercury) . . .	69° 17′.
Connellite (Sulphato Chloride of Copper) . .	Unknown.
Coquimbite	43° 50′.
Corundum	57° 34′.
Covelline	Unknown.
Cronstedtite	Unknown.
Davyne	59° 15′.
Diallogite (Carbonate of Manganese) . . .	43° 29′.
Dioptase	50° 39′.
Dolomite (Bitter Spar)	43° 52′.
Emerald	44° 56′.
Eudialyte	67° 42′.
Fluocerite (Neutral Fluate of Cerium) . . .	Unknown.
Gmelenite	Doubtful.
Graphite	Unknown.
Greenockite (Sulphuret of Cadmium) . . .	58° 47.′
Hematite (Specular Iron)	57° 30′.
Hydrargillite	Unknown.
Ice	Unknown.
Ilmenite	57° 30′.
Kupfernickel (Copper Nickel)	58° 36′.
Levyne	43° 59′,
Magnesite (Carbonate of Magnesia) . . .	43° 4′,
Mesitine	43° 14′.
Millerite (Native Nickel)	20° 50′.
Mimetite (Arseniate of Lead)	56° 19′.
Molybdenite (Sulphuret of Molybdena) . .	Uuknown.
Nepheline	59° 10′.

Nitratine (Nitrate of Soda)	43° 40′.
Osmiridium	58° 27′.
Parasite	81° 20′.
Phenakite	37° 19′.
Plattnerite	Unknown.
Polybasite	70° 31′.
Proustite (Red Silver)	42° 51′.
Pyrargyrite (Sulphuret of Silver and Antimony)	42° 18′.
Pyromorphite (Phosphate of Lead)	55° 49′.
Pyrosmalite	46° 42′.
Pyrrhotine (Magnetic Iron Pyrites)	60° 7′.
Quartz	51° 47′.
Ripidolite	66° 2′.
Riolite	Unknown.
Spartalite	37° 30′.
Stilpnomelane	Unknown.
Susannite	68° 38′.
Tamarite (Arseniate of Copper)	71° 16′.
Tellurium	57° 36′.
Tellurwismuth	Unknown.
Tetradymite	74° 44′.
Tourmaline	27° 20′.
Vanadinite (Vanadiate of Lead)	Unknown.
Willemite	30° 7′.
Xanthocone	69° 30′.

Hexagonal Prisms of the First and Second Order.—As in the pyramidal system, the two square prisms differ only in size and position, so in the rhomboidal

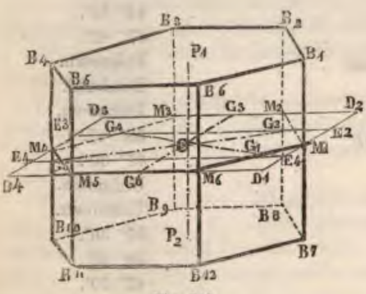


Fig. 249.

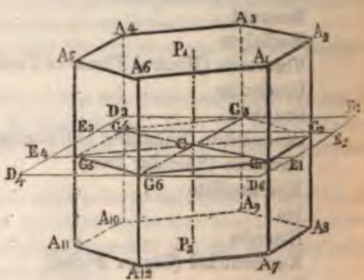


Fig. 25

system the hexagonal prisms differ from one another in the same manner. The hexagonal prism is a right prism standing on a base which is a regular hexagon; it is bounded therefore by eight faces, six of which—such as $B_1\ B_6\ B_{12}\ B_7$ (Fig. 249), and $A_1\ A_6\ A_{12}\ A_7$ (Fig. 250)—are rectangular parallelograms forming the sides of the prism; the other two faces, forming the top and bottom of the prism, are regular hexagons.

By many writers the sides only of the hexagonal prism are considered as the faces of the *hexagonal prism;* the form being considered an *open* one. The two hexagonal faces which *inclose* it are then called *basal pinacoids.*

Axes of the Hexagonal Prism, and of the Rhomboidal System.— Let P_1 and P_2 be the centres of the hexagonal faces of the two hexagonal prisms (Figs. 249 and 250).

Join $P_1 P_2$. Bisect $P_1 P_2$ in C.

Let M_1, M_2, &c., M_6, be the centres of the edges $B_1 B_7$, $B_2 B_8$, &c., $B_6 B_{12}$, of the hexagonal prism of the first order (Fig. 249).

Join $M_1 M_2$, $M_2 M_3$, &c., $M_6 M_1$.

Bisect $M_6 M_1$, $M_1 M_2$, M_2 M_3, &c., by G_1, G_2, G_3, &c.

Join G_1 G_4, G_2 G_5, and G_3 G_6, cutting one another in C.

Let G_1, G_2, &c., G_6, be the centres of the edges of the hexagonal prism of the second order (Fig. 250).

Join G_1 G_4, G_2 G_5, and G_3 G_6, cutting one another in C.

Then in the case of both prisms, P_1 P_2, G_1 G_4, G_2 G_5, and G_3 G_6 will be the axes of the prisms, and of the *rhomboidal system.*

It follows, therefore, that in this system there are four axes, three of which lie in the same plane, and are inclined to each other at an angle of 60°; and the third passes through their intersection, and is perpendicular to their plane. C G_1 C G_2 C G_3, are the three equal parameters of this system, and a fourth unequal parameter is taken in the axis C P_1. The forms of the rhomboidal system are derived from these axes by most of the continental crystallographers; but Professor Miller refers them to three equal axes derived from a particular rhomboid for each substance, in the following manner.

Let P_1 R_1 R_2, &c., P_2, (Fig. 251), be a particular rhomboid (*i. e.*, a figure bounded by six equal rhombs), chosen, for each substance which crystallizes in this system, as its typical form. Join the opposite angles of every face. Let H_1 be the point where P_1 R_1 meets R_2 R_6; H_1 is the centre of the face P_1 R_1 R_2 R_6. Let H_2, H_3, H_4, H_5 and H_6, be the centres of the other faces of the rhomboid found in a similar manner.

Fig. 251.

Join H_1 H_4, H_2 H_5, and H_3 H_6, the centres of the opposite faces of the rhomboid, cutting each other in the point C.

H_1 H_4, H_2 H_5, and H_3 H_6, will be the three equal axes of Professor Miller, and C H_1, C H_2, and C H_3, the three equal parameters.

Professor Miller refers the forms of the rhomboidal system to these three axes, equally inclined to one another, and with equal parameters. The inclination of these axes, and the length of the equal parameters, will differ for each particular substance, and depend upon its angular element. In the previous system of four axes, the inclination of the axes are the same for every substance; but the length of the unequal parameter will depend upon the angular element for each substance.

Both systems have their advantages. Professor Miller's is more consistent with the method adopted in other systems, as all of them are referred to three axes, and his formulæ also possess the advantage of being readily translated into those of Haüy, and the modifications of his system by Brooke and Levy. The system of four axes, however, by its formulæ, gives a clearer view of the relations of the various forms to each other; and the axis in which the unequal parameter is taken is one of considerable importance, being the optic axis, in the case of every transparent substance crystallizing in the forms of the rhomboidal system. For these reasons we shall adopt the system of four axes, translating its formulæ into those of Professor Miller.

Parameters.—Take any arbitrary line $C\,G_1$ (Fig. 252) as the length of the three equal parameters. With C as a centre, and $C\,G_1$ as radius, describe the circle $G_1\,G_2\,G_3$.

Take chords $G_1 G_2$, $G_2 G_3$, &c., $G_6\,G_1$, each equal to $C G_1$. Join $C G_2$, $C G_3$, &c., $C\,G_6$. $G_1\ G_2\ G_3$, &c., G_6, will be a regular hexagon inscribed in the circle $G_1\,G_2\,G_3$.

Fig. 252.

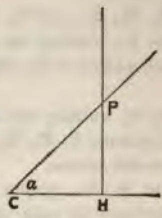


Fig. 253.

$G_1 G_4$, $G_2 G_5$, and $G_3 G_6$, will be three axes which lie in the same plane; $C\ G_1$, $C\,G_2$, $C\ G_3$, the three equal parameters.

To determine the fourth parameter which lies in the axis passing through C perpendicular to this plane, draw C H perpendicular to $G_1\ G_2$. Then (Fig. 253) take C H equal CH (Fig. 252), and draw C P, making an angle P C H, equal to the angle given as the angular element for the particular substance whose parameters are to be obtained.

Through H draw H P perpendicular to C H, and meeting C P in P, H P will be the length of the fourth parameter.

To Draw the two Hexagonal Prisms.—Through each of the points $G_1\ G_2$, &c., G_6 (Fig. 252), draw $M_6\ M_1$, $M_1\ M_2$, &c., $M_5\ M_6$, perpendicular to $C\ G_1$, $C\ G_2$, &c., $C\ G_6$, meeting each other in the points $M_1\ M_2$, &c., M_6. $M_1\ M_2$ and M_6 is a regular hexagon circumscribing the circle $G_1\ G_2\ G_3$.

$M_1\ M_2$, &c., M_6, is the hexagonal base of the *hexagonal prism of the first order.* $G_1\ G_2$, &c., G_6, that of the *hexagonal prism of the second order.*

Through M_1 and M_4 draw $D_1\ D_2$ and $D_4\ D_3$ parallel to $G_6\ G_3$, meeting $M_5\ M_6$ and $M_3\ M_2$ produced in the points $D_4\ D_1\ D_2$ and D_3.

Join $G_2\ G_4$ and $G_1\ G_5$, and produce both ways to meet $D_1\ D_2$ in E_2 and E_1, and $D_3\ D_4$ in E_3 and E_4.

Then for the *hexagonal prism of the first order* (Fig. 249) draw $D_1\ D_4$ equal $D_1\ D_4$ (Fig. 252), and $D_4\ D_3$, making an angle of about 30° with $D_4\ D_1$. Draw $D_1\ D_2$ parallel to $D_4\ D_3$.

In $D_1\ D_4$ (Fig. 249) take $D_1\ M_6$, $D_1\ G_6$, and $D_1\ M_5$, equal to $D_1\ M_6$, $D_1\ G_6$, and $D_1\ M_5$ (Fig. 252); also in $D_1\ D_2$ take $D_1\ E_1$, $D_1\ M_1$, $D_1\ E_2$, $D_1\ D_2$ (Fig. 249), each equal the half of $D_1\ E_1$, $D_1\ M_1$, $D_1\ E_2$, and $D_1\ D_2$ (Fig. 252).

Take $D_4\ E_4$, $D_4\ M_4$, $D_4\ E_2$, $D_4\ D_3$ (Fig. 249), each equal to $D_1\ E_1$, $D_1\ M_1$, $D_1\ E_2$, and $D_1\ D_2$ of the same figure. Join $D_2\ D_3$, and make $D_2\ M_2$, $D_2\ G_3$, $D_2\ M_3$, each equal to $D_1\ M_6$, $D_1\ G_6$, $D_1\ M_5$.

Join $M_1 M_6$, $M_1 M_2$, $M_3 M_4$, and $M_4 M_5$, also $E_1 E_4$, cutting $M_1 M_6$ in G_1, and $M_4 M_5$ in G_5, likewise join $E_1 E_2$, cutting $M_4 M_3$ in G_4, and $M_1 M_2$ in G_2.

Join $G_1 G_4$, $G_2 G_5$, and $G_3 G_6$, intersecting in the point C.

Through M_6 draw $M_6 B_6$ perpendicular to $M_6 M_5$. Take $M_6 B_6$ of any convenient length. Produce $B_6 M_6$ to B_{12}, make $M_6 B_{12}$ equal to $M_6 B_6$.

Through $M_1 M_2$, &c., M_5, draw $B_1 B_7$, $B_2 B_8$, &c., $B_5 B_{11}$, each parallel to $B_6 B_{12}$, and take $M_1 B_1$, $M_1 B_7$, &c., each equal to $M_6 B_6$.

Join $B_1 B_2$, $B_2 B_3$, &c., $B_6 B_1$, and $B_7 B_8$, $B_8 B_9$, &c., $B_{12} B_7$.

And the hexagonal prism of the first order will be constructed.

Through C draw $P_1 P_2$ parallel to $B_1 B_7$; take $C P_1$ and $C P_2$ equal to $M_1 B_1$. Then $P_1 P_2$, $G_1 G_4$, $G_2 G_5$, and $G_3 G_6$, are the four axes of this prism.

To draw the hexagonal prism of the second order, let $P_1 P_2$, $G_1 G_2 G_3$, &c., G_6 (Fig. 250), be determined in the same manner as in Fig. 249.

Through $G_1 G_2$, &c., G_6, draw $A_1 A_7$, $A_2 A_8$, &c., $A_6 A_{12}$, parallel to $P_1 P_2$, and $G_1 A_1$, $G_1 A_6$, $G_2 A_2$, &c., each equal to $C P_1$.

Join $A_1 A_2$, $A_2 A_3$, &c., and $A_7 A_8$, $A_8 A_9$, &c., and the hexagonal prism of the second order will be described.

$P_1 P_2$, $G_1 G_4$, $G_2 G_5$, and $G_3 G_6$, are the four axes of this prism.

Symbols.—Each face of the *hexagonal prism of the first order* cuts one of the axes in which the equal parameters are taken at distances equal to that parameter, and the two adjacent axes in the same plane at distances equal to twice the equal parameter, and is parallel to the axes in which the fourth unequal parameter is taken.

Thus the face $B_1 B_7 B_{12} B_6$ (Fig. 249), if produced, would cut the axis $C G_1$ in G_1, the axes $C G_6$, and $C G_2$ produced in points at a distance equal to twice $C G_1$ from C; it is also parallel to $C P_1$.

The symbol which represents these relations to the axes is 1, 2, ∞.

Naumann's symbol is ∞ P 2, Miller's $o\,\bar{1}\,1$, Brooke and Levy's modification of Haüy d^1, or g^1, according as the rhomboid or hexagonal prism is taken for the primitive.

Each face of the *hexagonal prism of the second order* cuts two adjacent axes, in which the equal parameters are taken, at distances from the centre, equal to the equal parameter, and is parallel to the axis in which the unequal parameter is taken.

Thus (Fig. 250) the face of the prism, $A_1 A_2 A_8 A_7$, cuts the axes $C G_1$ and $C G_2$ in the points G_1 and G_2, $C G_1$ and $C G_2$ being both equal to the equal parameter, and is parallel to the axis CP_1.

The symbol which represents these relations to the axes is 1 1 ∞, Naumann's symbol is ∞ P, Miller's, $2\,\bar{1}\,\bar{1}$, Brooke and Levy's, e^2 or *m*, according as the rhomboid or hexagonal prism is taken for the primitive.

The *basal pinacoids*, which inclose the prisms of both orders, are perpendicular to the axis C P, and parallel to the other axes; their symbol, therefore, is ∞ ∞ 1.

Naumann's symbol is *o* P, Miller's, 1 1 1, Brooke and Levy's a^1 or *p*, according as the rhomboid or hexagonal prism is taken for the primitive.

To describe a Net for the Hexagonal Prisms.—The regular hexagon $M_1 M_2$, &c., M_6 (Fig. 252), will form the top and bottom of the hexagonal prism of the first order, the hexagon $G_1 G_2$, &c., G_6, those of the hexagonal prism of the second order. Draw a rectangular parallelogram, having two of its opposite sides equal to the side of the regular hexagon, and the other two equal sides of any convenient length. Arrange two equal regular hexagons, and six equal parallelograms, as in Fig. 253, and the net will be constructed.

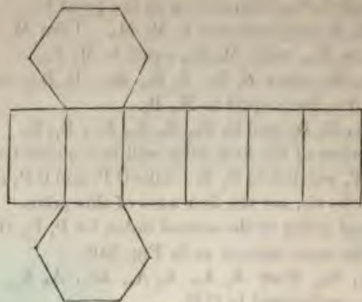


Fig. 254.

The hexagons being taken equal to M_1 M_2, &c., M_6, for the prism of the first order, and to G_1 G_2, &c., G_6, for that of the second order.

Minerals whose crystals present faces parallel to the hexagonal prism of the first order, whose symbol is 1 2 ∞, *Naumann* ∞ P 2, *Miller* 0 1 $\bar{1}$, *and Brooke and Levy* d^1 :—

Antimony.	Covelline.	Ice.	Pyrargyrite.
Apatite.	Davyne.	Ilmenite.	Pyromorphite.
Biotite.	Diallogite.	Kupfernickel.	Pyrosmalite.
Breithauptite.	Dioptase.	Millerite.	Pyrrhotine.
Brucite.	Dolomite.	Mimetite.	Quartz.
Calamine.	Emerald.	Molybdenite.	Ripidolite.
Calcite.	Endialyte.	Nepheline.	Spartalite.
Chabasie.	Fluocerite.	Osmiridium.	Tourmaline.
Chalybite.	Gmelinite.	Phenakite.	Vanadinite.
Connellite.	Greenockite.	Plattnerite.	Willemite.
Coquimbite.	Hematite.	Polybasite.	
Corundum.	Hydrargillite.	Proustite.	

Minerals whose crystals cleave parallel to this form, those printed in italics indicating that the cleavage is easy and perfect :—

Antimony.	Calcite.	Greenockite.	Pyrosmalite.
Apatite.	Emerald.	Nepheline.	*Spartalite.*
Brucite.	Endialyte.	Phenakite.	

Minerals whose crystals present faces parallel to the hexagonal prism of the second order, whose symbol is $\bar{1}$ 1 ∞, *Naumann* ∞ P, *Miller* 2 $\bar{1}$ $\bar{1}$, *Brooke and Levy* e^2 :—

Apatite.	Emerald.	Mimetite.	Ripidolite.
Calcite.	Endialyte.	Molybdenite.	Susannite.
Chalybite.	Graphite.	Nepheline.	Tamarite.
Cinnabar.	Greenockite.	Phenakite.	Tellurium.
Connellite.	Hematite.	Proustite.	Tellurwismuth.
Coquimbite.	Hydrargillite.	Pyrargyrite.	Tourmaline.
Corundum.	Ilmenite.	Pyromorphite.	Willemite.
Cronstedtite.	Mesitine.	Pyrrhotine.	
Davyne.	Millerite.	Quartz.	

Cleavages parallel to the prism of the second order occur in—

Calcite.
Cinnabar.
Cronstedtite.
Pyrrhotine.
Quartz.
Tellurium.
Willemite.

Minerals whose crystals present faces parallel to the basal pinacoids, symbol ∞ ∞ 1, *Naumann* o P, *Miller* 1 1 1, *Brooke and Levy* a^1 :—

Alunite.
Ankerite.
Antimony.
Apatite.
Arsenic.
Biotite.
Bismuth.
Breithauptite.
Brucite.
Calamine.
Calcite.
Chabasie.
Chalybite.
Clintonite.
Chlorite.
Cinnabar.
Coquimbite.
Corundum.
Cronstedtite.
Covelline.
Davyne.
Diallogite.
Dolomite.
Emerald.
Eudialyte.
Fluocerite.
Gmelinite.
Graphite.
Greenockite.
Hematite.
Hydrargillite.
Ice.
Ilmenite.
Kupfernickel.
Levyne.
Mesitine.
Mimetite.
Molybdenite.
Nepheline.
Osmiridium.
Parasite.
Plattnerite.
Polybasite.
Proustite.
Pyrargyrite.
Pyromorphite.
Pyrosmalite.
Pyrrhotine.
Quartz.
Ripidolite.
Spartalite.
Stilpnomelane.
Susannite.
Tamarite.
Tellurium.
Tellurwismuth.
Tetradymite.
Tourmaline.
Vanadinite.
Willemite.
Xanthocone.

Cleavages parallel to the basal pinacoids occur in the following minerals :—

Alunite.
Antimony.
Apatite.
Arsenic.
Biotite.
Bismuth.
Brucite.
Calcite.
Clintonite.
Chlorite.
Corundum.
Cronstedtite.
Covelline.
Emerald.
Endialyte.
Graphite.
Greenockite.
Hematite.
Hydrargillite.
Ice.
Ilmenite.
Nepheline.
Osmiridium.
Parasite.
Polybasite.
Pyrosmalite.
Pyrrhotine.
Ripidolite.
Spartalite.
Stilpnomelane.
Susannite.
Tamarite.
Tellurium.
Tellurwismuth.
Tetradymite.
Willemite.
Xanthocone.

Position of the poles of the hexagonal prisms and basal pinacoid on the sphere of projection of the rhomboidal system.—With C as centre, and any convenient radius C M_1 describe the circle M_1 M_2 M_4.

Let $M_1 M_4$ and $G_2 G_5$ be any two diameters at right angles to each other.

Take arcs M_1 G_1, $G_2 M_2$, $G_2 M_3$, and M_4 G_3, each equal to 30°.

Through G_1, M_2, M_3 and G_3, draw the diameters G_1 G_4, M_2 M_5, M_3 M_6, and G_3 G_6.

Then C will represent the north pole of the sphere of projection, and the circle M_1 G_1 M_4 its equator.

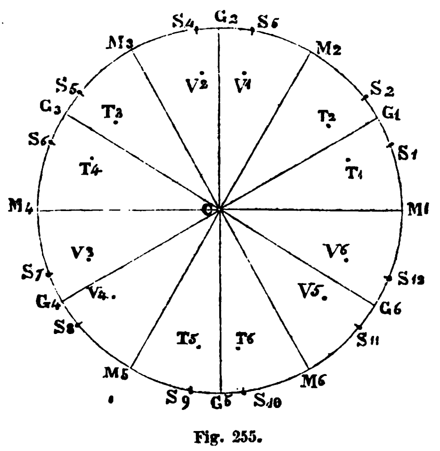


Fig. 255.

C will represent the pole of the upper ***basal pinacoid***, G_1 G_2, &c.. G_6, the poles of the ***hexagonal prism of the first order***, M_1 M_2, &c., M_6, the poles of the ***hexagonal prism of the second order***, G_1 C G_4, G_2 C G_5, and G_3 C G_6, the zones in which the poles of the ***six-faced pyramids of the first order*** lie, and M_1 C M_4, M_2 C M_5, and M_3 C M_6, the zones in which the poles of the ***six-faced pyramids of the second order*** lie.

One pole of the ***twelve-faced prism*** will lie in each of the arcs M G, and one pole of the ***double twelve-faced pyramid*** in each compartment of the sphere bounded by the arcs C M, M G, and G C.

Double Six-Faced Pyramid of the First Order.— The double six-faced pyramid consists of two pyramids joined together, one on each side of a regular hexagonal base. It is bounded by twelve triangular faces, such as P_1 M_1 M_6 (Fig. 256), each face being an isosceles triangle. It has six *four-faced solid angles*, M_1 M_2, &c., M_6, and two *six-faced solid angles*, P_1 and P_2.

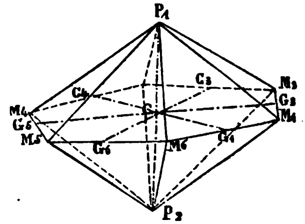


Fig. 256.

There are six equal edges, M_1 M_2, &c., which are the sides of the common hexagonal base, and twelve other edges, P_1 M_1, P_1 M_2, &c., equal to each other, but unequal to the former, which form the sides of the isosceles triangles. The hexagonal base of this pyramid is the hexagon circumscribing the circle described with one of the equal parameters for its radius.

To Draw the Double Six-faced Pyramid of the First Order.—Prick off the points M_1, M_2, &c., M_6, G_1, G_2, &c., G_6, P_1, P_2, and C, from Fig. 249.

Join M_1 M_2, M_2 M_3, &c., M_6 M_1, G_1 G_4, G_2 G_5, &c., and P_1 P_2.

Take C P_1 and C P_2, equal H P (Fig. 253), the unequal parameter.

Join P_1 M_1, P_1 M_2, &c., P_2 M_1, P_2 M_2, &c., and the pyramid will be constructed.

Axes.—The axes G_1 C_1, G_2 C_1, and G_3 C, in which the equal parameters lie, join the centres of the opposite edges of the hexagonal base of the pyramid; while the *fourth* axis, P_1 P_2, along which the unequal parameter is measured, joins the opposite apices of the pyramids.

Symbols.—Each face of the pyramid would, if produced, cut one of the axes in which the equal parameters are taken at the extremity of the parameter, the neighbouring axis in the hexagonal base at a distance from its centre twice that of the equal parameter, and the fourth axis perpendicular to the base at the extremity of the unequal parameter. Thus the face P_1 M_1 M_6, if produced, cuts the axis C G_1 at G_1, C G_6 at a distance from C equal twice C G_1, and C P_1 at P_1.

The symbol which expresses this relation to the axes is 1, 2, 1. Naumann's symbol for this form is P 2, or R ∞, Miller's 5, 2, $\bar{1}$, Brooke and Levy's $d^{\frac{1}{2}}$ $d^{\frac{1}{4}}$ b^1, if the rhomboid, and a^2 if the hexagonal prism be taken as the primitive form.

Inclination of the Faces.—Let ϕ be the angle of inclination of the faces measured over the edges M_1 M_2, M_2 M_3, &c.; θ their inclination over the edges P_1 M_1, P_1 M_2, &c.; α the angular element; and λ the latitude of the faces measured from the pole C (Fig. 255), or the angle between the axis P_1 P_2, and the normals of the faces.

Then $\tan. \lambda = \cos. 30° \tan. \alpha \quad \cos. \frac{\theta}{2} = \sin. 30° \sin \lambda \quad \text{and } \phi = 2 \lambda.$

Position of the Poles on the Sphere of Projection.—The meridians of longitude in which the poles of this pyramid lie, will be those of 30°, 90°, and 150°, on both sides of M_1 C M_4; or four poles will lie in each zone G_1 C G_4, G_2 C G_5, and G_3 C G_6. Six poles will lie in the circle of latitude λ° north, and six in the same parallel of south latitude.

Crystals whose Faces occur parallel to the Double Six-faced Pyramid of the first order, with the Latitude of their Poles on the sphere of projection.

Apatite	51° 44′.
Breithauptite	56° 5.′
Emerald	40° 50′.
Quartz	47° 43′.

Double Six-faced Pyramids derived from the Pyramid of the First Order.—From the preceding pyramid others may be derived, by retaining the same base, and joining its angular points with points equidistant from C in the line P_1 P_2, or P_1 P_2 produced. Let Q_1 and Q_2 be these points. C Q_1 and C Q_2 are always some multiple *m* of the line C P. *m* may be any whole number or fraction.

When *m* is less than unity, or a proper fraction, Fig. 257 represents the pyramid which is more obtuse than Fig. 256, from which it is derived.

When *m* is greater than unity, Fig. 258 represents the pyramid which in this case is more acute than Fig. 256, from which it is derived.

Symbols.—Each face of this pyramid would, if produced, cut one of the axes in which the equal parameters are taken at the extremity of the parameter; the neigh-

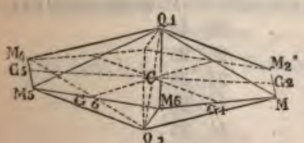


Fig. 257.

Fig. 258.

bouring axis in the hexagonal base, at a distance from its centre being twice that of the equal parameter, and the fourth axis perpendicular to the plane of the base of the pyramid, at a distance from the centre equal to *m* times the unequal parameter.

When *m* becomes infinitely great, the pyramid becomes the prism of the first order.

The symbol which expresses this relation to the axes is 1, 2, *m*. Naumann's symbol for these pyramids is m P 2, or m R ∞; Miller's h, k, l; and Brooke and Levy's modification of Haüy $\overline{a^m}^{\,2}$, if the hexagonal prism be taken as the primitive form. Their symbol, if the rhomboid be taken as the primitive form, will be given under each particular form.

Inclination of the Faces.—If λ be the angle of latitude of the faces, θ their inclination over the edges $Q_1 M_1$, $Q_2 M_2$, &c., ϕ over the edges $M_1 M_2$, $M_2 M_3$, &c., α the angular element for the substance,

Then $\tan. \lambda = m \cos. 30° \tan. \alpha$,

$$\cos. \frac{\theta}{2} = \sin. 30° \sin. \lambda, \text{ and } \phi = 2 \lambda.$$

Position of the Poles of this Form on the Sphere of Projection.—The poles of these pyramids always lie in the same zones as the pyramid of the first order from which they are derived; six being in the circle of latitude $\lambda°$ north, and six in the same latitude south.

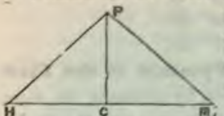


Fig. 259.

To describe the net for these Pyramids.—Draw C M_1 and C P (Fig. 259) perpendicular to each other. Take C M_1 equal to C M_1 (Fig. 252), C P equal C P_1 (Fig. 256), or C Q_1 (Figs. 257 and 258). Join P M_1.

Fig. 260.

Then Fig. 260.—Draw M_1 M_2 equal M_1 M_2 (Fig. 252). On M_1 M_2 describe the isosceles triangle P M_1 M_2, having its sides P M_1 and P M_2 equal P M_1 (Fig. 259).


Fig. 261.

P M_1 M_2 will be a face of the pyramid, and twelve such faces, arranged as in Fig. 261, will form the required net.

Forms of the Double Six-faced Pyramids derived from the pyramid of the first order which occur in nature, together with the Latitude of their Faces.

The form 1, 2, $\frac{1}{3}$; $\frac{1}{3}$ P 2 Naumann; 2 3 1 Miller; a^6 or $b^1 b^{\frac{1}{2}}$ $b^{\frac{1}{3}}$ Brooke and Levy.

Apatite	22° 55′.
Breithauptite . . .	26° 22′.
Davyne	25° 53′.
* Greenockite . . .	25° 28′.
Hematite	24° 22′.

The form 1, 2, $\frac{8}{9}$; $\frac{8}{9}$ P 2 Naumann; 3 7 $\bar{1}$ Milller; $a^{\frac{6}{4}}$ or $d^{\frac{1}{3}}$ $d^{\frac{1}{7}}$ $b^{\frac{1}{3}}$ Brooke and Levy.

Ripidolite	60° 00′.

The form 1, 2, $\frac{4}{3}$; $\frac{4}{3}$ P 2 Naumann; 1 3 $\bar{1}$ Miller; $a^{\frac{3}{2}}$ or e_3 Brooke and Levy.

Apatite	59° 24′.
Chalybite	47° 30′.
Corundum	61° 11′.
Emerald	49° 2′.
*Greenockite . . .	62° 18′.
Hematite	61° 7′.
Ilmenite	61° 7′.
Mimetite	60° 0′.

Nepheline	62° 40′.
Osmiridium	62° 0′.
Parasite	82° 29′.
Phenakite	19° 17′.
Pyromorphite	59° 32′.
Pyrosmalite	50° 47′.
Pyrrhotine	63° 25′.

The form 1, 2, $\frac{2}{3}$; $\frac{2}{3}$ P 2 Naumann; 1 2 0 Miller; a^3 or b^2 Brooke and Levy.

Apatite	40° 13′.
Calcite	29° 40′.
Chabasie	35° 15′.
Coquimbite	29° 0′.
Davyne	44° 8′.
Emerald	29° 57′.
Gmelinite	40° 4′.
*Greenockite	43° 37′.
Hematite	42° 11′.
Kupfernickel	43° 25′.
Mimetite	40° 54′.
Molybdenite	Undetermined.
Nepheline	44° 3′.
†Phenakite	11° 37′.
Plattnerite	Undetermined.
Polybasite	58° 30′.
Pyrargyrite	27° 43′.
Pyromorphite	40° 22′.
Pyrosmalite	31° 30′.
Pyrrhotine	63° 25′.

Mimetite and Pyromorphite cleave parallel to this form.

The form 1, 2, $\frac{14}{9}$; $\frac{14}{9}$ P 2 Naumann; 3 10 $\bar{4}$ Miller; $a^{\frac{9}{7}}$ or $d^{\frac{1}{3}}\,d^{\frac{1}{16}}\,b^{\frac{1}{4}}$ Brooke and Levy.

Corundum	64° 45′.

The form 1, 2, 2; 2 P 2 Naumann; 1 4 $\bar{2}$ Miller; a^1 or $d^1\,d^{\frac{1}{4}}\,b^{\frac{1}{2}}$ Brooke and Levy.

Apatite	68° 29′.
Biotite	78° 8′.
Corundum	69° 51′.
Quartz	65° 33′.

The form 1, 2, $\frac{7}{3}$; $\frac{7}{3}$ P 2 Naumann; 2 9 $\bar{5}$ Miller; $a_{\frac{3}{14}}$ or $d^{\frac{1}{2}}\,d^{\frac{1}{5}}\,b^{\frac{1}{5}}$ Brooke and Levy.

Corundum	72° 31′.

The form 1, 2, $\frac{8}{3}$; $\frac{8}{3}$ P 2 Naumann; 1 5 $\bar{3}$ Miller; $a^{\frac{3}{4}}$ or $d^1\,d^{\frac{1}{5}}\,b^{\frac{1}{3}}$ Brooke and Levy.

Biotite	81° 3′.
Calcite	66° 18′.
Corundum	74° 36′.
*Greenockite	75° 18′.
Mimetite	73° 54′.
Pyromorphite	73° 37′.
Spartalite	60° 34′.

The form 1, 2, $\frac{10}{3}$; $\frac{10}{3}$ P 2 Naumann; $1\,6\,\bar{4}$ Miller; $a^{\frac{3}{5}}$ or $d^1 d^{\frac{1}{8}}\ b^{\frac{1}{4}}$ Brooke and Levy.

Hematite	77° 33′.
Ilmenite	77° 33′.

The form 1, 2, 4; 4 P 2 Naumann; $17\bar{5}$ Miller; $a^{\frac{1}{2}}$ or $d^1 d^{\frac{1}{7}}\ b^{\frac{1}{5}}$ Brooke and Levy.

Apatite	78° 51′.
Biotite	84° 0′.
Calcite	73° 41′.
Corundum	79° 36′.
Hematite	79° 45′.

The form 1, 2, 5; 5 P 2 Naumann; 2, 17, $\overline{13}$ Miller; $a^{\frac{2}{5}}$ or $d^{\frac{1}{2}}\ d^{\frac{1}{7}}\ b^{\frac{1}{13}}$ Brooke and Levy.

Emerald	76° 58′.

The form 1, 2, $\frac{16}{3}$; $\frac{16}{3}$ P 2 Naumann; $1\ 9\ \bar{7}$ Miller; $a^{\frac{3}{8}}$ or $d^1 d^{\frac{1}{9}}\ b^{\frac{1}{7}}$ Brooke and Levy.

Corundum	82° 10′.

The form 1, 2, 8; 8 P 2 Naumann; 1, 13, $\overline{11}$ Miller; $a^{\frac{1}{4}}$ or $d^1 d^{\frac{1}{13}}\ b^{\frac{1}{11}}$ Brooke and Levy.

Corundum	84° 45′.

The forms of Greenockite, marked thus *, are sometimes hemihedral, with parallel faces; that of Phenakite, marked †, hemihedral, with inclined faces. The hemihedral forms, with parallel faces, are *rhomboids;* those with inclined faces, double *three-faced pyramids.*

Double Six-faced Pyramid of the Second Order.—The double six-faced pyramid of the second order is the same form of solid as the pyramid of the first order, and differs from it only in its position and relation to the axes of the system. The base of this pyramid, $G_1\ G_2$, &c., G_6 (Fig. 262) is the hexagon $G_1\ G_2$, &c., G_6 (Fig. 252) inscribed in the circle whose radius, $C\ G_1$, is equal to one of the equal parameters.

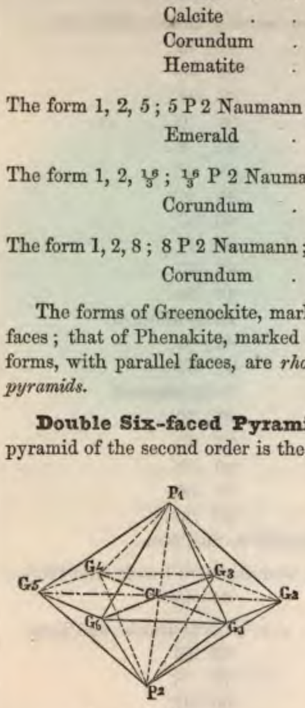


Fig. 262.

To Draw the Double Six-faced Pyramid of the Second Order.—Prick off the points $G_1\ G_2$, &c., G_6, $P_1\ C_1\ P_2$, from Fig. 250. Take $C\ P_1$ and $C\ P_2$, equal H P (Fig. 253), the unequal parameter. Join $P_1\ G_1$, $P_1\ G_2$, &c., and the pyramid will be constructed.

Axes.—The axis $P_1\ P_2$, in which the unequal parameter is taken, joins the opposite six-faced solid angles P_1 and P_2; while the axes in which the equal parameters are taken, such as $G_1\ G_4$, join the opposite four-faced solid angles. Each face, therefore, of this pyramid cuts three axes at the extremities of their parameters.

Symbols.—The symbol which expresses the above relation of the faces of this pyramid to its axis is 111.

Naumann's symbol for this form is P. Miller, Brooke, and Levy do not treat this pyramid as a distinct form, but regard it as a combination of the two equal rhomboids which are its parallel hemihedral forms.

Inclination of the Faces.—Let ϕ be the angle of inclination of the faces measured over the edges $P_1 G_1$, $P_2 G_2$, &c., θ their inclination over the edges $G_1 G_2$, $G_2 G_3$, &c., a the angular element.

$$\theta = 2\, a \qquad \cos. \frac{\phi}{2} = \frac{1}{2} \sin. a.$$

Position of the Poles on the Sphere of Projection.—The poles of the faces of this pyramid lie in the meridians of 0°, 60°, and 120°, six in the circle of latitude a° north, and six in the same circle of south latitude; or four poles lie in each of the zones M_1 C M_4, M_2 C M_5, and M_3 C M_6 (Fig. 255).

Double Six-faced Pyramids derived from the Pyramid of the Second Order.—Retaining the same base, other pyramids may be derived from that of the second order by taking points Q_1 and Q_2 in C P or C P produced, such that C Q_1 or C Q_2 is equal to m times C P_1 (Fig. 262); m being a whole number or fraction greater than unity for the pyramid Fig. 264, and less than unity for Fig. 263.

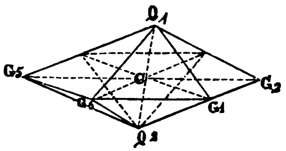


Fig. 263.

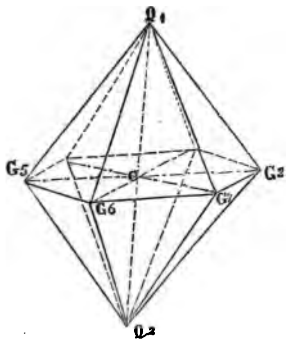


Fig. 264.

When m becomes infinitely great, the pyramid becomes the prism of the second order.

Symbols.—The symbol for these pyramids is 11 m, Naumann's m P.

Inclination of the Faces.—If ϕ be the angle of inclination of the faces measured over the edges $Q_1 G_1$, $Q_2 G_1$, &c., θ over the edges $G_1 G_2$, $G_2 G_3$, &c., a the angular element of the substance, and λ the inclination of the normals of the faces to $Q_1 Q_2$, or their latitude on the sphere of projection,

$$\tan. \lambda = m \tan. a \qquad \theta = 2\, \lambda, \text{ and } \cos. \frac{\phi}{2} = \frac{1}{2} \sin. \lambda.$$

Position of the Poles on the Sphere of Projection.—The poles of the faces of these pyramids lie in the meridians of 0°, 60°, and 120°, six for each pyramid in the circle of latitude λ° north, and six in the same circle of south latitude; or four poles lie in each of the zones M_1 C M_4, M_2 C M_5, and M_3 C M_6 (Fig. 255).

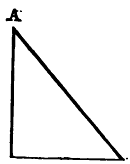


Fig. 265.

Nets for these Pyramids.—Take B C (Fig. 265), equal to C G_1 (Fig. 252). Draw B A perpendicular to B C. Take A B equal to C Q (Figs. 262 or 263); that is, equal to m times the unequal parameter. Join A C.

Then (Fig. 266) draw $G_1 G_2$ equal $G_1 G_2$ (Fig. 252); on it describe the isosceles triangle P G_1 G_2, having the sides P G_1 and P G_2 equal A C (Fig. 265).

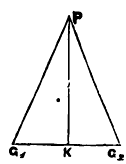


Fig. 266.

P G_1 G_2 is a face of the pyramid; and twelve such faces, arranged as in Fig. 261, will form the required net.

These pyramids occur so seldom, as homohedral or perfect forms in nature, that when they do so, they are regarded as combinations of the two hemihedral forms derived from them; we shall therefore describe them under their hemihedral forms.

Rhomboid.—The rhomboid may be considered as a hemihedral form with parallel faces of the double six-faced pyramid. The positive rhomboid (Fig. 267) is derived

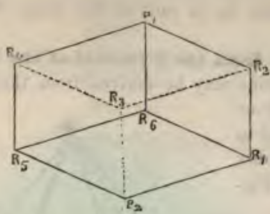


Fig. 267.

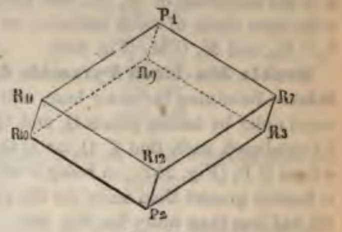


Fig. 268.

from the pyramid Fig. 262 by producing the faces P_1 G_1 G_2, P_1 G_3 G_4, P_1 G_5 G_6, P_2 G_1 G_6, P_2 G_2 G_3, and P_2 G_4 G_5 to meet one another. The negative rhomboid (Fig. 268) is formed by producing the other six faces of the pyramid.

The rhomboid is bounded by six equal faces, each of which, such as P_1 R_6 R_1 R_2, are rhombs; that is, four-sided figures, with equal sides and opposite angles, but all the angles not equal. It has twelve equal edges, two *three-faced solid angles*, P_1 and P_2 (Figs. 267 and 268), formed by the union of three equal angles of the rhombic faces, and six *three-faced solid angles*, R_1 R_2, &c. (Fig. 267), R_{10} R_{11}, &c. (Fig. 268), formed by the union of two equal angles of the rhombic faces with an unequal one.

To draw the Rhomboid.—Though the Rhomboid is derived from the double six-faced pyramid as its hemihedral form, and might be constructed from that figure by producing its faces, it is more easily obtained from the hexagonal prism of the first order.

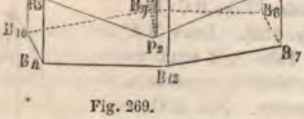


Fig. 269.

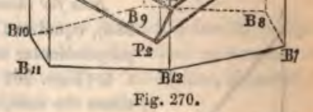


Fig. 270.

For Figs. 269 and 270, prick off from Fig. 249 all the points marked P C B and M. Take P C and B_1 M_1, B_2 M_2, &c., in both Figs. equal to the unequal parameter P C (Fig. 262), as determined for the particular substance whose rhomboid is to be drawn. Join all the B's and P_1 C P_2.

Then for the positive rhomboid (Fig. 269), take R_6 M_6 equal one-third of M_6 B_6,

$M_1 R_1$ one-third of $M_1 B_7$, and so on, taking care that the points R are alternately above and below the points M.

Join P_1 with R_6, R_2 and R_4; and P_2 with R_1, R_3 and R_5; and R_6 R_1 R_2 R_3 R_1 R_5 and R_6, and the positive rhomboid will be constructed.

The negative rhomboid is constructed by taking M R one-third of M B alternately above and below M, as shown in Fig. 270, and joining the points B and R.

Symbols.—The symbol for the rhomboids derived from the pyramid whose symbol is 111, is $+\left[\frac{111}{2}\right]$ and $-\left[\frac{111}{2}\right]$, Naumann's symbol is $+\frac{P}{2}$ and $-\frac{P}{2}$ or $+$ R and $-$ R.

Miller's symbol for the *positive rhomboid* is 100, Brooke and Levy's P, if that rhomboid be taken as the primative form, $\frac{1}{2}(b^1)$ if the hexagonal prism be chosen for the primative.

Miller's symbol for the *negative rhomboid* is $\bar{1}$ 2 2, Brooke and Levy's $e^{\frac{1}{2}}$ or $\frac{1}{2}(b^1)$, according as the rhomboid or the hexagonal prism are taken as the primative form.

Inclination of the Faces of the Rhomboid.—If θ be the angles of inclination over any of the edges P R (Figs. 267 and 268), ϕ over the edges R R, and α the angular element.

$$\cos.\frac{\theta}{2} = \sin.\ 60\ \sin.\ \alpha \quad \text{and } \phi = 180^\circ - \theta.$$

α is the latitude of the faces of the rhomboids on the sphere of projection.

Poles of the Rhomboids on the Sphere of Projection.—The poles of the positive rhomboid on the northern half of the sphere of projection (Fig. 255), are the points where

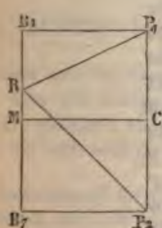


Fig. 271.

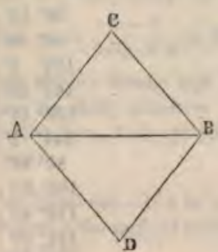


Fig. 272.

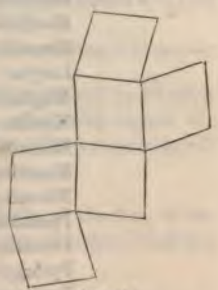


Fig. 273.

the circle of latitude, α, cuts the meridian C M_1, C M_3 and C M_5, the poles of the negative rhomboid where the same circle cuts the meridians C M_2, C M_4, and C M_6.

Nets for the Rhomboids.—Take C M (Fig. 271) equal C M (Fig. 252), draw P_1 C P_2 perpendicular to M C_1, take C P_1 and C P_2 equal C P_1 (Fig. 269 or 270).

Through M draw B_1 B_7 parallel to P_1 P_2 and through P_1 and P_2, P_1 B_1 and P_2 B_7 parallel to C M.

Take R M one-third of B_1 M. Join P_1 R and R P_2.

Then (Fig. 272) draw A B equal R P_2 (Fig. 271), on A B describe an isosceles triangle A C B, having its sides A C, B C equal P_1 R (Fig. 271). Describe a similar and equal triangle A D B on the other side of A B. The figure C A D B will be a face of the rhomboid, and six such faces, arranged, as in Fig. 273, will form the required net.

Faces parallel to those of the Positive Rhomboid occur in nature in the following subs… The angles are those of the inclinations of their faces θ and φ. The angle of their la… being the same as the angular element, is not given.

Alunite	92° 50′; 87° 10′.
Ankerite	106° 12′; 73° 48′.
Antimony	87° 35′; 92° 25′.
Apatite.	88° 42′; 91° 18′.
Arsenic	85° 41′; 94° 19′.
Biotite	71° 4′; 108° 56′.
Bismuth	87° 40′; 92° 20′.
Breunnerite	107° 23′; 72° 37′.
Calamine	107° 40′; 72° 20′.
Calcite	105° 5′; 74° 55′.
Chabasie	94° 46′; 85° 14′.
Chalybite	106° 60′; 73° 0′.
Cinnabar	71° 48′; 108° 12′.
Corundum	86° 4′; 93° 56′.
Cronstedtite	Undetermined.
Diallogite	106° 51′; 73° 9′.
Dioptase	95° 54′; 84° 6′.
Dolomite	106° 15′; 73° 45′.
Emerald	104° 34′; 75° 26′.
Eudialyte	73° 30′; 106° 30′.
Gmelinite	Doubtful.
Hematite	86° 10′; 93° 50′.
Ilmenite	86° 10′; 93° 50′.
Levyne	106° 4′; 73° 56′.
Magnesite	107° 29′; 72° 31′.
Mesitine	107° 14′; 72° 46′.
Millerite	144° 8′; 35° 52′.
Mimetite	86° 48′; 93° 12′.
Nitratine	106° 33′; 73° 27′.
Phenakite	116° 40′; 63° 20′.
Proustite	107° 50′; 72° 10′.
Pyrargyrite	106° 42′; 73° 18′.
Pyromorphite	88° 28′; 91° 32′.
Pyrrhotine	82° 40′; 97° 20′.
Quartz	94° 15′; 85° 45′.
Ripidolite	75° 22′; 104° 22′.
Spartalite	116° 30′; 63° 30′.
Susannite	72° 30′; 107° 30′.
Tamarite	69° 48′; 110° 12′.
Tellurium	86° 2°; 93° 58′.
Tetradymite	66° 40′; 113° 20′.
Tourmaline	133° 8′; 46° 52′.
Willemite	128° 30′; 51° 30′.
Xanthocone	63° 18′; 116° 42′.

Cleavages parallel to the positive Rhomboid occur in the following minerals, the cleavage being perfect in those printed in italics.

Alunite.	*Diallogite.*	*Mesitine.*	*Pyrargyrite.*
Ankerite.	*Dolomite.*	*Millerite.*	Quartz.
Calcite.	Eudialyte.	*Nitratine.*	*Tourmaline.*
Chabasie.	Hematite.	Phenakite.	*Willemite.*
Chalybite.	Ilmenite.	Proustite.	*Xanthocone.*
Corundum.	*Magnesite.*		

Cronstedtite, Phenakite, and Pyrargyrite present hemihedral forms of the six-faced pyramid with inclined faces. This form is a double three-faced pyramid.

Faces parallel to the negative Rhomboid occur in the following minerals.

Apatite	88° 42′; 91° 18′	Phenakite	116° 40′; 63° 20′
Calcite	105° 5′; 74° 55′	Pyromorphite	88° 28′; 91° 32′
Corundum	86° 4′; 93° 56′	Pyrrhotine	82° 40′; 97° 20′
Dioptase	95° 54′; 84° 6′	Quartz	94° 15′; 85° 45′
Emerald	104° 34′; 75° 26′	Ripidolite	75° 22′; 104° 22′
Hematite	86° 10′; 93° 50′	Susannite	72° 30′; 107° 30′
Millerite	144° 8′; 35° 52′	Tellurium	86° 2′; 93° 58′
Mimetite	86° 48′; 93° 12′		

Millerite and Quartz are the only minerals which cleave parallel to the negative rhomboid, the cleavage of the first being perfect.

Rhomboids may be derived from each of the double six-faced pyramids (page 397), whose symbol is 11 m; to draw them we have only to make C P in Figs. 269 and 270 equal to m times the unequal parameter. Their nets may be constructed in a similar manner by making C P in Fig. 271 equal to the same quantity.

Symbols.—The symbols for these rhomboids will be $\left[\frac{11\,m}{2}\right]$, Naumann's $\frac{m\,\text{P}}{2}$ or m R, and Miller's $h\ k\ k$, where $m = \frac{h-k}{h+2\,k}$ is the relation existing between the numbers used by Naumann and Miller; Brooke and Levy's symbol will be $b^{\frac{1}{m}}$ when they take the hexagonal prism for their primitive form; when they regard the positive rhomboid as their primitive form, their symbols for the derived rhomboids will be given with each particular case.

Inclination of the Faces of the Rhomboids.—If λ be the latitude of the face of the rhomboid, and α its angular element, ϕ the angle of inclination over the edges PR, θ that over the edges RR (Figs. 267 and 268),

$$\tan.\ \lambda = m \tan.\ \alpha, \quad \cos.\ \frac{\phi}{2} = m \sin.\ 60 \cos.\ \lambda \tan.\ \alpha,$$
$$\text{and } \theta = 180° - \phi.$$

Rhomboids derived from the Double Six-faced Pyramids (p. 397), *whose Faces have been observed in nature, together with their Latitude on the Sphere of Projection.*

$\frac{1}{16}$ R Naumann; 655 Miller; $a^{\frac{6}{5}}$ Brooke and Levy.
Hematite . . 5° 36′

$-\frac{1}{8}$ R Naumann; 233 Miller; $a^{\frac{3}{2}}$ Brooke and Levy.
Hematite . . 11° 6′

$-\frac{1}{5}$ R Naumann; 122 Miller; $a^{\frac{1}{2}}$ Brooke and Levy.
Hematite . . 17° 26′

$\frac{1}{4}$ R Naumann; 211 Miller; a^2 Brooke and Levy.

Antimony	20° 40′	Cinnabar	33° 28′	Hematite	21° 25′	Pyrargyrite	12° 49′
Calcite	13° 52′	Eudialyte	31° 22′	Proustite	13° 3′	Tetradymite	42° 30′

Eudialyte cleaves parallel to this form.

$-\frac{1}{4}$ R Naumann; 255 Miller; $a^{\frac{2}{5}}$ Brooke and Levy.

Calcite	13° 52′	Hematite	21° 25′

$-\frac{2}{7}$ R Naumann; 133 Miller; $a^{\frac{1}{3}}$ Brooke and Levy.

Hematite	24° 9′

$\frac{1}{5}$ R Naumann; 522 Miller; $a^{\frac{5}{2}}$ Brooke and Levy.

Corundum	27° 41′	Cinnabar	41° 24′

$\frac{2}{5}$ R Naumann; 311 Miller; a^3 Brooke and Levy.

Cinnabar	46° 39′	Ilmenite	32° 7′

$\frac{1}{2}$ R Naumann; 411 Miller; a^4 Brooke and Levy.

Apatite	36° 13′	Hematite	38° 7′	Quartz	32° 25′
Corundum	38° 12′	Millerite	10° 46′	Tamarite	55° 51′

$-\frac{1}{2}$ R Naumann; 011 Miller; b^1 Brooke and Levy.

Ankerite	25° 42′	Calcite	26° 15′	Dolomite	25° 40′	Phenakite	20° 52′
Antimony	37° 2′	Chabasie	31° 22′	Eudialyte	50° 38′	Proustite	24° 53′
Apatite	36° 13′	Chalybite	25° 17′	Hematite	38° 7′	Pyrargyrite	24° 28′
Arsenic	38° 30′	Cinnabar	52° 54′	Ilmenite	38° 7′	Quartz	32° 25′
Bismuth	36° 58′	Diallogite	25° 23′	Mesitine	25° 11′	Tamarite	55° 51′
Breunnerite	25° 6′	Dioptase	31° 22′	Millerite	10° 46′	Tourmaline	14° 20′
Calamine	24° 58′						

Antimony, Bismuth, Chalybite, Diallogite, Hematite, Ilmenite, Proustite, Dioptase, and Millerite, cleave parallel to this form, the last two perfectly.

$\frac{5}{8}$ R Naumann; 611 Miller; a^6 Brooke and Levy.

Hematite	44° 27′

$\frac{2}{3}$ R Naumann; 711 Miller; a^7 Brooke and Levy.

Calcite	33° 20′

$-\frac{4}{5}$ R Naumann; $\bar{1}33$ Miller; $e^{\frac{1}{3}}$ Brooke and Levy.

Calcite	38° 17′

$-\frac{2}{5}$ R Naumann; $\bar{2}, 11, 11$ Miller; $e^{\frac{7}{11}}$ Brooke and Levy.

Calcite	49° 49′

$-\frac{5}{4}$ R Naumann; $\bar{2}33$ Miller; $e^{\frac{2}{3}}$ Brooke and Levy.

Calcite	50° 58′

$-\frac{3}{2}$ R Naumann; $\bar{4}55$ Miller; $e^{\frac{4}{5}}$ Brooke and Levy.

Arsenic	67° 16′	Calcite	55° 57′	Hematite	66° 59′	Proustite	54° 18′

$\frac{4}{3}$ R Naumann; $13, \bar{2}, \bar{2}$ Miller; $e^{\frac{13}{2}}$ Brooke and Levy.

Quartz	64° 43′

$\frac{7}{4}$ R Naumann; $6, \bar{1}, \bar{1}$ Miller; e^6 Brooke and Levy.

Ripidolite	75° 45′

2 R Naumann; $5\bar{1}\bar{1}$ Miller; e^5 Brooke and Levy.

Apatite	71° 9′	Quartz	68° 31′

-2 R Naumann; $\bar{1}11$ Miller; e^1 Brooke and Levy.

Antimony	71° 40′	Chabasie	67° 47′	Ilmenite	72° 20′	Ripidolite	77° 28′
Apatite	71° 9′	Chalybite	62° 7′	Levyne	62° 37′	Susannite	78° 56′
Biotite	79° 41′	Corundum	72° 22′	Phenakite	56° 44′	Tetradymite	82° 14′
Bismuth	71° 37′	Dolomite	62° 31′	Proustite	61° 41′	Tourmaline	45° 57′
Calamine	61° 46′	Eudialyte	78° 25′	Pyrargyrite	71° 13′	Willemite	49° 14′
Calcite	63° 7′	Hematite	72° 20′	Quartz	68° 31′	Xanthocone	79° 25′

Antimony, Bismuth, Levyne, and Tourmaline, cleave parallel to this form.

$\frac{5}{4}$ R Naumann; $4\bar{1}\bar{1}$ Miller; e^4 Brooke and Levy.

Hematite	75° 42′	Ilmenite	75° 42′	Ripidolite	79° 55′

$-\frac{5}{2}$ R Naumann; $\bar{8}77$ Miller; $e^{\frac{8}{7}}$ Brooke and Levy.

Calcite . . . 67° 56′

3 R Naumann; $7\bar{2}\bar{2}$ Miller; $e^{\frac{7}{2}}$ Brooke and Levy.

Quartz . . . 75° 18′

$-$ 3 R Naumann; $\bar{5}44$ Miller; $e^{\frac{5}{4}}$ Brooke and Levy.

Calcite . . . 71° 20′ | Levyne . . 70° 57′ | Millerite . . 48° 47′

$-\frac{7}{2}$ R Naumann; $\bar{4}33$ Miller; $e^{\frac{4}{3}}$ Brooke and Levy.

Calamine . . 72° 56′ | Calcite . . . 73° 51′ | Quartz . . 77° 19′ | Tourmaline . 61° 4′

4 R Naumann; $3\bar{1}\bar{1}$ Miller; e^{3} Brooke and Levy.

Calamine . . 74° 58′	Dolomite . . 75° 25′	Pyrargyrite . 74° 38′	Spartalite . 71° 57′
Calcite . . . 75° 47′	Hematite . . 80° 57′	Quartz . . 78° 52′	Tourmaline . 64° 11′
Chalybite . . 75° 11′			

$-$ 4 R Naumann; $\bar{7}55$ Miller; $e^{\frac{7}{5}}$ Brooke and Levy.

Calcite . . . 75° 47′

$-$ 5 R Naumann; $\bar{3}22$ Miller; $e^{\frac{3}{2}}$ Brooke and Levy.

Calamine . . 77° 53′	Chalybite . 78° 3′	Ilmenite . . 82° 44′	Tourmaline . 68° 51′
Calcite . . . 78° 32′	Hematite . . 82° 44′	Pyrargyrite . 82° 11′	

$\frac{11}{2}$ R Naumann; $8\bar{3}\bar{3}$ Miller; $e^{\frac{8}{3}}$ Brooke and Levy.

Quartz . . 81° 51′

6 R Naumann; $1\bar{3}, \bar{5}, 5$ Miller; $e^{\frac{13}{5}}$ Brooke and Levy.

Quartz . . 82° 31′

$-$ 7 R Naumann; $\bar{13}, 8, 8$ Miller; $e^{\frac{13}{8}}$ Brooke and Levy.

Quartz . . 83° 35′ | Susannite . 68° 38′

$-$ 8 R Naumann; $\bar{5}33$ Miller; $e^{\frac{5}{3}}$ Brooke and Levy.

Calcite . . . 82° 47′

$-$ 11 R Naumann; $\bar{7}44$ Miller; $e^{\frac{7}{4}}$ Brooke and Levy.

Quartz . . 85° 54′

Poles of the derived Rhomboids.—The poles of the positive rhomboids, that is of those rhomboids whose symbol, according to Naumann, is of the form *m*R, will be found by observing the points where the circle of latitude for λ° north cuts the meridians CM_1, CM_3, and CM_5 (Fig. 255), of the northern hemisphere of the sphere of projection, and where the same circle of south latitude cuts the meridians CM_2, CM_4, and CM_6 in the southern hemisphere. In the case of the negative rhomboids, or those whose symbol is — *m*R, the poles will be the intersection of the circle of north latitude λ, with the meridians CM_2 CM_4, and CM_6, and the same circle of south latitude with the meridian CM_1, CM_3, and CM_5.

Circle of Latitude on Sphere of Projection.—We here beg to call our readers' attention to an omission which we find we have made in the early part of our treatise. We ought to have warned our students that it is far more convenient for purposes of crystallography to reckon the degrees of latitude from the pole to the equator instead of from the equator to the pole. Strictly speaking, the angle which we have called the angle of latitude is the north or south polar distance. Our angle of latitude is always, therefore, the difference between 90° and the angle of latitude as reckoned on a celestial or terrestrial globe. This observation applies to the cubical and pyramidal systems.

The Right Prism on a Twelve-sided Base.—This prism, also called the *dihexagonal prism*, is a solid bounded by fourteen faces, twelve of which, such as L_1 L_7 G_7 G_1 (Fig. 274), are rectangular parallelograms, forming the sides of the prism; the other two, which terminate the prism, being irregular polygons, with twelve sides.

When this prism is considered an open form, its sides alone are taken for the planes of the prism, and the two faces which inclose it are considered faces of the same *basal pinacoids* which inclose the hexagonal prisms.

To Draw the Dihexagonal Prism.—Take any arbitrary line, CG_1 (Fig. 275), for one of the three equal parameters (as in Fig. 252, page 385); draw CG_2, CG_3, CG_4, &c.,

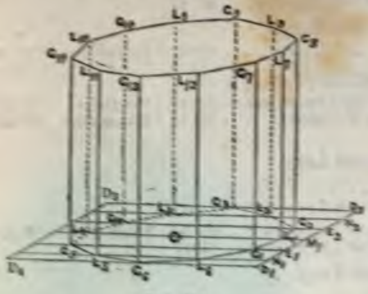


Fig. 274.

Fig. 275.

CG_6, each equal to CG_1, and inclined to each other at an angle of 60°. Join $G_1 G_2$, $G_2 G_3$, &c., $G_5 G_6$; $G_1 G_2 G_3$ &c. G_6 will be a regular hexagon, and $G_1 G_4$, $G_2 G_5$, and $G_3 G_6$ will represent the three axes of the hexagonal system in which the equal parameters are taken.

Draw CL_1, CL_2, CL_3, &c., CL_6 bisecting the angles G_1CG_2, G_2CG_3, &c., G_6CG_1. Then Fig. 276, draw the equilateral triangle $CG_1 G_2$ equal CG_1G_2 (Fig. 275); bisect G_1CG_2 by CH, produce CG_1 and CG_2 to K_1 and K_2; take CK_1 and CK_2 each equal *n* times CG_1, the symbol for the prism being 1 *n* ∞. Join $G_1 K_2$ and $G_2 K_1$ cutting CH produced in L. Lastly, in Fig. 275, take CL_1, CL_2, CL_3, &c., CL_6 each equal to CL (Fig. 276); join $G_1 L_1$, $L_1 G_2$, $G_2 L_2$, $L_2 G_3$, &c., and $G_1 L_1 G_2 L_2$ &c. $L_6 G_1$, will be the base of the prism. Through G_6 and G_3 draw the lines $D_4 G_6 D_1$ and $D_3 G_3 D_2$ parallel to L_4CL_1; take $G_6 D_1$ equal to any line greater than CL_1; $G_6 D_4$,

Fig. 276.

$G_3 D_2$ and $G_3 D_3$, each equal to $G_6 D_1$.

Join $D_1 D_2$ and $D_4 D_3$; produce $L_3 L_6$ to meet $D_2 D_3$ in M_3, and $D_1 D_4$ in M_6, and $L_6 L_3$ to meet $D_2 D_3$ in M_3, and $D_1 D_4$ in M_6.

Join $L_5 L_{10}$, $G_5 G_{12}$, $G_4 G_2$ and $L_9 L_{10}$, and produce these lines as well as $L_4 L_1$ to meet $D_1 D_2$ and $D_4 D_3$ in the points NE and M, as indicated in Fig. 275.

Draw $D_1 D_4$ (Fig. 274) equal $D_1 D_4$ (Fig. 275), and $D_1 D_2$ and $D_4 D_3$, each making an angle of 30°, to $D_1 D_4$. Take $D_1 D_2$ and $D_4 D_3$ equal to the half of $D_1 D_2$ and $D_4 D_3$ in Fig. 275.

In $D_1 D_2$ (Fig. 274) take $D_1 N_1$, $D_1 E_1$, $D_1 N_2$, $D_1 E_2$, $D_1 N_2$, each half of $D_1 N_1$, $D_1 E_1$, $D_1 M_1$, &c., respectively, in Fig. 275.

Through N_1, E_1, M_1, E_2 and N_2 draw $N_1 N_2$, $E_1 E_4$, $M_1 M_4$, $E_2 E_3$ and $N_2 N_3$ parallel to $D_1 D_4$. Take $N_1 L_6$, $N_1 L_{10}$, $E_1 G_1$, $E_1 G_5$, $M_1 L_1$, $M_1 L_4$, $E_2 G_2$, $E_2 G_6$, $N_2 L_2$, $N_2 L_3$, $D_1 G_6$ and $D_2 G_3$ respectively equal to $N_1 L_6$, $N_1 L_5$, $E_1 G_2$, $E_1 G_3$, &c. (Fig. 275). Draw $G_6 G_{12}$ perpendicular to $D_1 D_4$, take $G_6 G_{12}$ equal the height of the prism intended to be represented; draw $L_6\,L_{12}$, $G_1\,G_7$, $L_1\,L_7$, &c., as in Fig. 274, parallel and equal to $G_6\,G_{12}$; join $G_{12}\,L_{12}$, $L_{12}\,G_7$, &c., and the *right prism on a twelve-sided base* will be drawn in isometrical perspective.

Axes.—$G_1\,G_4$, $G_2\,G_5$, and $G_3\,G_6$ (Fig. 274) represent the three axes in which the equal parameters are taken. The fourth axis corresponds to the geometrical axis of the prism, and would be represented by a line drawn through C parallel to $G_6\,G_{12}$.

Symbols.—Each face of the prism, if produced, would cut one of the three equal axes at a distance from the centre equal to the arbitrary unit, and an adjacent axis at n times this distance, and is parallel to the fourth axis.

The symbol which expresses this relation to the axes is $1\ n\ \infty$. Naumann's symbol for this form is $\infty\ P\ n$; and Miller's $h\ k\ l$. $h\ k\ l$ and n may be obtained from each other by the formulæ

$$n = \frac{h-l}{h-k} \text{ and } h+k+l=o.$$

To describe a Net for the Right Prism on a Twelve-sided Base.—Draw two twelve-sided polygons, each equal to $G_1\,L_1\,G_2\,L_2$, &c., $L_6\,G_1$ (Fig. 275), and twelve rectangular parallelograms, each equal in breadth to $G_1\,L_1$ (Fig. 275), and of a length equal to that of the prism intended to be represented. Arrange these fourteen figures as in Fig. 277, and the net will be constructed.

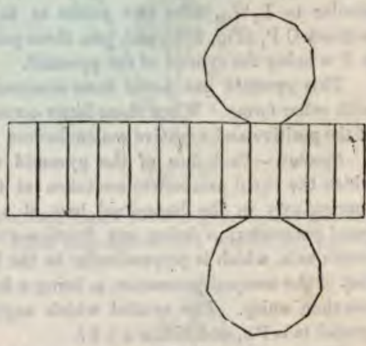


Fig. 277.

Position of the Poles of the Prism on the Sphere of Projection.—The poles of the faces of the *dihexagonal prism* always lie in the same zone, and that zone is the equator of the sphere of projection; S_1, S_2, S_3, S_4, &c., S_{12} (Fig. 255) represent these poles, the arcs $G_1\,S_1$, $G_1\,S_2$, $G_2\,S_5$, $G_2\,S_4$, &c., being equal to each other. Let θ be the angle M_1CS_1, or the longitude of the pole S_1 reckoning from M_1.

$$\tan\theta = \sqrt{3}\,\frac{n-1}{n+1} = \sqrt{3}\,\frac{k-l}{2h-k-l}.$$

Forms of the Dihexagonal Prism, parallel to which Faces have been observed in nature, with the Longitude of their Poles on the Sphere of Projection.

The form $1\ \frac{8}{7}\ \infty$; $\infty\ P\ \frac{8}{7}$ Naumann; $5\ \bar{2}\ \bar{3}$ Miller; and $d^{\frac{1}{2}}\ d^{\frac{1}{3}}\ b^{\frac{1}{5}}$ Brooke and Levy; longitude 6° 35′ occurs in Corundum and *Dioptase.

The form $1\ \frac{6}{5}\ \infty$; $\infty\ P\ \frac{6}{5}$ Naumann; $11\ \bar{4}\ \bar{7}$ Miller; $d^{\frac{1}{4}}\ d^{\frac{1}{7}}\ b^{\frac{1}{11}}$ Brooke and Levy; longitude 8° 57′ occurs in Quartz.

The form $1\ \frac{5}{4}\ \infty$; $\infty\ P\ \frac{5}{4}$ Naumann; $3\ \bar{1}\ \bar{2}$ Miller; $d^{1}\ d^{\frac{1}{2}}\ b^{\frac{1}{3}}$ Brooke and Levy; longitude 10° 54′ occurs in *Apatite, Emerald, Hematite, *Phenakite, and Tourmaline.

The form $1\ \frac{4}{3}\ \infty$; $\infty\ P\ \frac{4}{3}$ Naumann; $7\ \bar{2}\ \bar{5}$ Miller; $d^{\frac{1}{2}}\ d^{\frac{1}{5}}\ b^{\frac{1}{7}}$ Brooke and Levy; longitude 13° 54′ occurs in Calcite and *Dioptase.

The form $1\ \frac{7}{5}\ \infty$; $\infty\ P\ \frac{7}{5}$ Naumann; $4\ \bar{1}\ \bar{3}$ Miller; $d^1\ d^{\frac{1}{3}}\ b^{\frac{1}{4}}$ Brooke and Levy; longitude 16° 6′ occurs in Tourmaline.

The form $1\ \frac{3}{2}\ \infty$; $\infty\ P\ \frac{3}{2}$ Naumann; $5\ \bar{1}\ \bar{4}$ Miller; $d^1\ d^{\frac{1}{4}}\ b^{\frac{1}{5}}$ Brooke and Levy; longitude 19° 6′ occurs in *Apatite, *Dioptase, and Millerite.

The forms marked thus * are hemihedral, with parallel faces; the hemihedral form of this prism with parallel faces is a regular hexagonal prism, arising from the development of the alternate faces, and differs only from the prisms of the First and Second Order, in its position with regard to the axes.

Double Twelve-faced Pyramid.—The *double twelve-faced pyramid*, or, as it is generally called, the *dihexagonal pyramid*, consists of two pyramids joined together, one on each side of the dihexagonal base given in Fig 275. It is bounded by twenty-four equal and similar scalene triangles, it has twelve *four-faced solid angles* at the base of the pyramids, and two *twelve-faced solid angles*, one at each apex of the double pyramid.

This pyramid may be easily drawn; through C, in Fig 274, draw a line perpendicular to $L_1\ L_4$, take two points in this line equidistant from C, and each equal m times $C\ P_1$ (Fig. 256), and join these points with $G_1\ G_2$, &c., G_6 and $L_1\ L_2$, &c., L_6; $m\ P\ n$ being the symbol of the pyramid.

This pyramid has never been observed alone, and scarcely ever in combination with other forms. When these latter occur, they may be regarded as the combination of the positive and negative scalenohedron derived from it.

Symbols.—Each face of the pyramid would, if produced, cut one of the axes in which the equal parameters are taken at the extremity of the parameter; the neighbouring axis in the hexagonal base at a distance from its centre n times that of the equal parameter, n being any fraction greater than one, and less than two; and the fourth axis, which is perpendicular to the base, at a distance from the centre m times that of the unequal parameter, m being a fraction or whole number equal to, greater, or less than unity. The symbol which expresses this relation is $1\ m\ n$. Naumann's symbol is $m\,P\,n$, and Miller's $h\ k\ l$.

When m becomes infinitely great this pyramid passes into the *dihexagonal prism*, and when m is finite and n becomes equal to two, it passes into a *double six-faced pyramid*, derived from that of the *First Order*.

Position of the Poles on the Sphere of Projection.—Twelve poles lie in the same circle of north latitude and twelve in the same circle of south latitude, one pole lies within each spherical triangle C G M (Fig. 255), two poles lie in the same circle of latitude at equal angular distances on each side of every meridian C G, such as $T_1\ T_2$ on both sides of $C\ G_1$ and $V_1\ V_2$ on both sides of $C\ G_2$.

The formulæ for determining the latitude and longitude of these poles, from the symbols for their forms, as well as the relation between $m\ n\ h\ k$ and l, will be given under the description of the hexagonal scalenohedron.

Hexagonal Scalenohedron.—The *hexagonal scalenohedron* is a hemihedral form with parallel faces, derived from the *double twelve-faced pyramid* by producing half the faces of the upper pyramid taken in pairs to meet half the faces of the lower one which do not correspond to those taken from the upper. Thus the faces whose poles are T_1, V_6, T_3, V_2, V_4, and T_5 in the northern hemisphere of projection (Fig. 255), being produced to meet one another, and the faces whose poles are T_2, V_1, T_4, V_3, T_6, and V_5 of the southern hemisphere, will form the positive scalenohedron. The twelve remaining faces if produced to meet each other will form the negative scalenohedron.

The hexagonal scalenohedron is bounded by twelve equal and similar scalene triangles, such as $K_1 R_1 R_2$ (Fig. 278), and $K_1 R_{12} R_7$ (Fig. 279); it has two six-faced solid

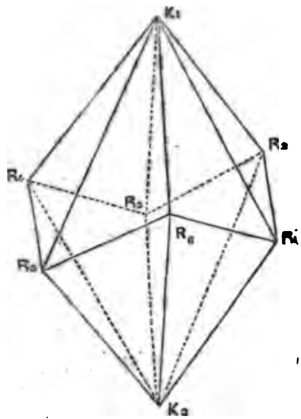


Fig. 278.

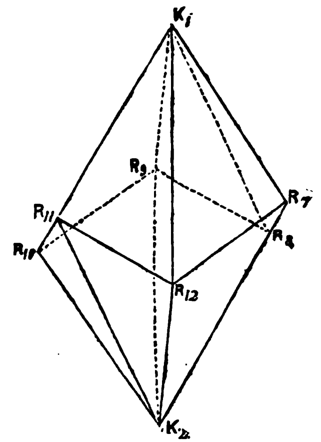


Fig. 279.

angles, K_1 and K_2 (Figs. 278 and 279), and six four-faced solid angles R_1, R_2, &c., R_6 (Fig. 278), and R_7, R_8, &c., R_{12} (Fig. 279). The four-faced solid angles are joined

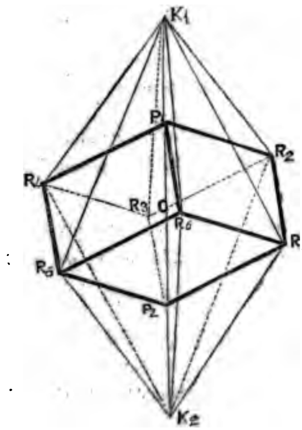


Fig. 280.

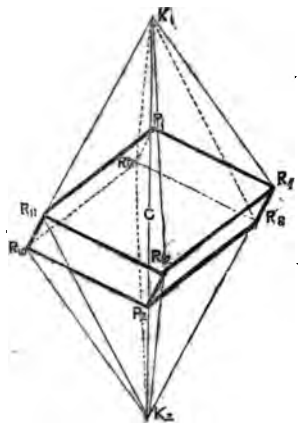


Fig. 281.

together by six equal edges, such as $R_1 R_2$ (Fig. 278,) and $R_{11} R_{12}$ (Fig. 279). These edges *correspond to the edges* of a rhomboid which may be inscribed in the scalenohedron, with the same axes as the figure in which it is inscribed. The remaining twelve edges are equal in pairs, six being longer and six shorter, the longer and shorter edges joining the six-faced solid angles with the four-faced, alternately, as shown in Figs. 278 and 279.

To draw the Hexagonal Scalenohedron.—Though the hexagonal scalenohedron is derived from the double twelve-faced pyramid, by the development of half its faces, and might be constructed from that figure, it is more readily obtained from the positive or negative rhomboid which may be supposed to be inscribed in the scalenohedron.

Let two rhomboids (Figs. 280 and 281) be drawn as directed for Figs. 269 and 270. Produce C P_1 and C P_2 to K_1 and K_2 (Figs. 280 and 281), make C K_1 equal C K_2, then (Fig. 280) join K_1 R_1, K_1 R_2, &c., K_1 R_6; K_2 R_1, K_2 R_2, &c., K_2 R_6, also in Fig. 281 join K_1 R_7, K_1 R_8, &c., K_1 R_{12}; K_2 R_7, K_2 R_8, &c., K_2 R_{12}. Fig. 280 will give the positive, and Fig. 281 the negative scalenohedron, the combination of whose faces together would give the double twelve-faced pyramid.

Symbols. — If m P n be Naumann's symbol for the double twelve-faced pyramid from which the scalenohedron is derived, his symbol for the latter will be $+\left[\frac{m\text{ P }n}{2}\right]$ or $-\left[\frac{m\text{ P }n}{2}\right]$ according as the scalenohedron is positive or negative.

Naumann's symbol for the rhomboid inscribed in the scalenohedron whose symbol is $\left[\frac{m\text{ P }n}{2}\right]$ is $\frac{m(2-n)}{n}$R; and C K is equal to $\frac{n}{2-n}$ times C P, hence Naumann chooses the arbitrary symbol $\frac{m(2-n)}{n}\ \text{R}^{\frac{n}{2-n}}$ to represent the scalenohedron $\left[\frac{m\text{ P }n}{2}\right]$.

To describe, therefore, the scalenohedron derived from the double twelve-faced pyramid m P n, we must describe the rhomboid $\frac{m(2-n)}{n}$R, produce C P_1 and C P_2 (Figs. 280 and 281), and make C K equal $\frac{n}{2-n}$ times C P.

Miller's symbol for the scalenohedron is $\pi\left\{h\ k\ l\right\}$; where $m = \frac{h-l}{h+k+l}$ and $n = \frac{h-l}{h-k}$ are the relations between Naumann's and Miller's symbols for the same form.

Nets for the Scalenohedrons.

Describe the triangle RP_1 P_2 (Fig. 282) as in Fig. 271, to form the net of the rhomboid whose symbol is $\frac{m(2-n)}{n}$R. Bisect P_1 P_2 in C, produce CP_1 to K_1, make CK_1 equal $\frac{n}{2-n}$ times CP_1, produce CP_2 to K_2, and make CK_2 equal CK_1. Join K_1R and K_2R.

Then (Fig. 283) draw LM equal RP_1; on LM describe the triangle LMN, having its side LN equal RK_1, and its side MN equal RK_2. LMN will be a face of the scalenohedron $\frac{m(2-n)}{n}\ \text{R}^{\frac{n}{2-n}}$, and twelve such faces, arranged as in Fig. 284, will form the net required.

Position of the Poles of the Hexagonal Scalenohedron on the Sphere of Projection.— If $m\mathrm{P}n$ be the symbol of the double twelve-faced pyramid from which the scalenohedron is derived, take an arc $M_1 S_1$, such that $\tan MS_1 = \sqrt{3}\frac{n-1}{n+1}$, mark off arcs $M_1 S_{12}$, $M_2 S_2$, $M_2 S_5$, &c., $M_6 S_{10}$, $M_6 S_{11}$, as in Fig. 255. Join CS_1, CS_2, CS_3, &c., CS_{12}. Let θ be the angular distance of a circle of latitude from C, such that $\tan \theta = \frac{m}{n}\sqrt{n^2 - n + 1}\tan \alpha$, where α is the angular element for the substance of the crystal given in pages 385 and 386. Then this circle of latitude will cut the meridians CS_1, CS_2, CS_5, CS_4, &c., in the points T_1, T_2, V_1, V_2, &c., as in Fig. 255.

T_1, T_2, V_1, V_2, &c., will be the poles of the double twelve-faced pyramid on the sphere of projection.

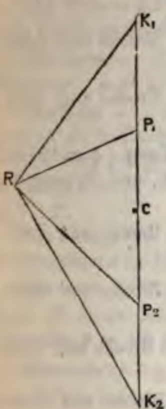


Fig. 282.

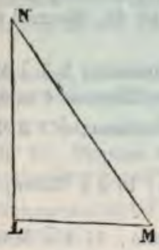


Fig. 283.

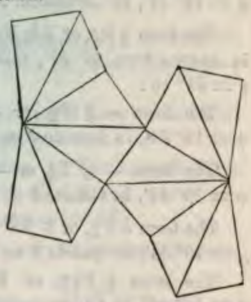


Fig. 284.

The poles $T_1\, V_2\, T_3\, V_4\, T_5\, V_6$ will be those of the positive, and $T_2\, V_1\, T_4\, V_3\, T_6\, V_5$ those of the negative scalenohedron on the northern sphere of projection.

The arc MS, which we may consider the longitude of the pole T, from the meridian CM_1, we shall represent by the symbol ϕ.

Faces of Scalenohedrons and other forms derived from the Double Twelve-faced Pyramids occur in Nature, in Crystals of the following substances.

The form $-13\ \mathrm{P}\frac{13}{12}$, or $-11\ \mathrm{R}^{\frac{13}{11}}$, Naumann; $\bar{8}\ 5\ 4$ Miller; $d^{\frac{1}{5}}\ d^{\frac{1}{4}}\ b^{\frac{1}{8}}$ Brooke and Levy. $\phi = 3°\ 58'$, in Quartz $\theta = 86°\ 24'$.

The form $\frac{6}{5}\ \mathrm{P}\frac{12}{11}$, or $\mathrm{R}^{\frac{6}{5}}$, Naumann; $11\ 0\ \bar{1}$ Miller; d^4 Brooke and Levy. $\phi = 4°\ 18'$, in Dioptase $\theta = 54°\ 35'$.

The form $\frac{3}{2}\ \mathrm{P}\frac{9}{8}$, or $\frac{7}{6}\ \mathrm{R}^{\frac{9}{7}}$ Naumann; $7\ 1\ \bar{2}$ Miller; $d^{\frac{1}{7}}\ d^1\ b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 5°\ 49'$, in Pyrargyrite $\theta = 52°\ 20'$.

The form $-\frac{8}{13}\ \mathrm{P}\frac{8}{7}$, or $-\frac{6}{13}\ \mathrm{R}^{\frac{4}{3}}$ Naumann; $22\ 19\ \bar{2}$ Miller; $d^{\frac{1}{22}}\ d^{\frac{1}{19}}\ b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 6°\ 35'$, in Quartz $\theta = 36°\ 25'$.

The form $\frac{4}{3}\ \mathrm{P}\frac{8}{7}$, or $\mathrm{R}^{\frac{4}{3}}$, Naumann; $0\ 7\ \bar{1}$ Miller; d^7 Brooke and Levy. $\phi = 6°\ 35'$, in Dioptase $\theta = 56°\ 55'$.

The form $8\ \mathrm{P}\frac{8}{7}$, or $6\ \mathrm{R}^{\frac{4}{3}}$, Naumann; $16\ \bar{5}\ \bar{8}$ Miller; $d^{\frac{1}{5}}\ d^{\frac{1}{8}}\ b^{\frac{1}{16}}$ Brooke and Levy. $\phi = 6°\ 35'$, in Quartz $\theta = 84°\ 3'$.

The form $\frac{7}{8}P\frac{7}{6}$, or $\frac{5}{8}R^{\frac{7}{5}}$ Naumann; 7 1 0 Miller; b^7 Brooke and Levy. $\phi = 7° 35'$, in Calcite $\theta = 38° 58'$.

The form $\frac{7}{5}P\frac{7}{6}$, or $R^{\frac{7}{5}}$ Naumann; 6 0 $\bar{1}$ Miller; d^6 Brooke and Levy. $\phi = 7° 35'$, in Calcite $\theta = 52° 18'$.

The form $\frac{6}{7}P\frac{6}{5}$, or $\frac{4}{7}R^{\frac{3}{2}}$ Naumann; 6 1 0 Miller; b^6 Brooke and Levy. $\phi = 8° 57'$, in Calcite $\theta = 38° 8'$.

The form $\frac{3}{2}P\frac{6}{5}$, or $R^{\frac{3}{2}}$ Naumann; 5 0 $\bar{1}$ Miller; d^5 Brooke and Levy. $\phi = 8° 57'$, in Calcite $\theta = 53° 57'$.

The form $6P\frac{6}{5}$, or $4R^{\frac{3}{2}}$ Naumann; 4 $\bar{1}$ $\bar{2}$ Miller; $d^1\, d^{\frac{1}{2}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 8° 57'$, in Dolomite $\theta = 79° 25'$, and Quartz $\theta = 81° 57'$.

The form $\frac{10}{9}P\frac{5}{4}$, or $\frac{2}{3}R^{\frac{5}{3}}$ Naumann; $\bar{3}$ 7 5 Miller; $d^{\frac{1}{7}}\, d^{\frac{1}{5}}\, b^{\frac{1}{3}}$ Brooke and Levy. $\phi = 10° 54'$, in Corundum $\theta = 58° 2'$.

The form $\frac{5}{3}P\frac{5}{4}$, or $R^{\frac{5}{3}}$ Naumann; 0 4 $\bar{1}$ Miller; d^4 Brooke and Levy. $\phi = 10° 54'$, in Apatite $\theta = 69° 57'$, Calcite $\theta = 56° 26'$, Emerald $\theta = 56° 44'$, and Pyrargyrite $\theta = 54° 16'$.

The form $-\frac{5}{3}P\frac{5}{4}$, or $-R^{\frac{5}{3}}$ Naumann; 2 3 $\bar{2}$ Miller; $e_{\frac{3}{2}}$ Brooke and Levy. $\phi = 10° 54'$, in Apatite $\theta = 69° 57'$, and Emerald $\theta = 56° 44'$.

The form $-\frac{10}{3}P\frac{5}{4}$, or $-2R^{\frac{5}{3}}$ Naumann; $\bar{5}$ 3 5 Miller; $e_{\frac{3}{5}}$ Brooke and Levy. $\phi = 10° 54'$, in Calcite $\theta = 71° 39'$.

The form $5P\frac{5}{4}$, or $3R^{\frac{5}{3}}$ Naumann; 10 $\bar{2}$ $\bar{5}$ Miller; $d^{\frac{1}{2}}\, d^{\frac{1}{5}}\, b^{\frac{1}{10}}$ Brooke and Levy. $\phi = 10° 54'$, in Quartz $\theta = 80° 15'$.

The form $\frac{7}{4}P\frac{14}{11}$, or $R^{\frac{7}{4}}$ Naumann; 11 0 $\bar{3}$ Miller; $d^{\frac{11}{3}}$ Brooke and Levy. $\phi = 11° 44'$, in Calcite $\theta = 57° 35'$.

The form $-\frac{9}{4}P\frac{9}{7}$, or $-\frac{5}{4}R^{\frac{9}{5}}$ Naumann; $\bar{4}$ 3 5 Miller; $d^{\frac{1}{3}}\, d^{\frac{1}{5}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 12° 13'$, in Calcite $\theta = 63° 39'$.

The form $-\frac{4}{9}P\frac{4}{3}$ or $-\frac{2}{9}R^2$ Naumann; 11 14 2 Miller; $b^{\frac{1}{11}}\, b^{\frac{1}{14}}\, b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 13° 54'$ in Quartz $\theta = 26° 58'$.

The form $\frac{4}{5}P\frac{4}{3}$, or $\frac{2}{5}R^2$ Naumann; 4 1 0 Miller; b^4 Brooke and Levy. $\phi = 13° 54'$ in Calcite $\theta = 35° 26'$ and Pyrargyrite $\theta = 33° 16'$.

The form $2P\frac{4}{3}$, or R^2 Naumann; 3 0 $\bar{1}$ Miller; d^3 Brooke and Levy. $\phi = 13° 54'$ in Calcite $\theta = 60° 39'$, Dioptase $\theta = 65° 33'$, Hematite $\theta = 46° 4'$, Phenakite $\theta = 53° 37'$, and Tourmaline $\theta = 42° 59'$.

The form $-2P\frac{4}{3}$, or $-R^2$ Naumann; 7 4 $\bar{5}$ Miller; $d^{\frac{1}{7}}\, d^{\frac{1}{4}}\, b^{\frac{1}{5}}$ Brooke and Levy. $\phi = 13° 54'$, in Dioptase $\theta = 65° 33'$.

The form $4P\frac{4}{3}$, or $2R^2$ Naumann; 8 $\bar{1}$ $\bar{4}$ Miller; $d^1\, d^{\frac{1}{4}}\, b^{\frac{1}{8}}$ Brooke and Levy. $\phi = 13° 54'$ in Quartz $\theta = 77° 41'$.

The form $-4P\frac{4}{3}$, or $-2R^2$ Naumann; $\bar{2}$ 1 2 Miller; $e_{\frac{1}{2}}$ Brooke and Levy. $\phi = 13° 54'$, in Calcite $\theta = 74° 18'$, Phenakite $\theta = 70° 0'$, Quartz $\theta = 77° 41'$, and Tourmaline $\theta = 61° 47'$.

The form $-\frac{13}{3}P\frac{13}{9}$, or $-\frac{5}{3}R^{\frac{13}{5}}$ Naumann; $\overline{16}$ 17 8 Miller; $d^{\frac{1}{17}}\, d^{\frac{1}{8}}\, b^{\frac{1}{16}}$ Brooke and Levy. $\phi = 15° 18'$, in Quartz $\theta = 76° 31'$.

The form $\frac{7}{6}P\frac{7}{5}$, or $\frac{1}{2}R^{\frac{7}{3}}$ Naumann; 1 6 $\bar{1}$ Miller; e_6 Brooke and Levy. $\phi = 16° 6'$, *in Apatite* $\theta = 56° 44'$.

The form $-\frac{7}{6}$ P $\frac{7}{5}$, or $-\frac{1}{2}$ $R^{\frac{7}{3}}$ Naumann; 3 5 $\bar{2}$ Miller; $d^{\frac{1}{3}}\, d^{\frac{1}{5}}\, b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 16° 6'$, in Apatite $\theta = 56° 44'$.

The form $-\frac{14}{9}$ P $\frac{7}{5}$, or $-\frac{2}{3}$ $R^{\frac{7}{3}}$ Naumann; $\bar{5}$ 5 9 Miller; $e_{\frac{2}{5}}$ Brooke and Levy. $\phi = 16° 6'$, in Calcite $\theta = 53° 52'$.

The form $\frac{7}{3}$ P $\frac{7}{5}$, or $R^{\frac{7}{3}}$ Naumann; 0 5 $\bar{2}$ Miller; $d^{\frac{5}{2}}$ Brooke and Levy. $\phi = 16° 6'$, in Apatite $\theta = 75° 0'$, and Calcite $\theta = 64° 2'$.

The form $-\frac{7}{3}$ P $\frac{7}{5}$, or $-R^{\frac{7}{3}}$ Naumann; $\bar{3}$ 4 2 Miller; $d^{\frac{1}{3}}\, d^{\frac{1}{4}}\, b^{\frac{1}{3}}$ Brooke and Levy. $\phi = 16° 6'$, in Apatite $\theta = 75° 0'$ and Calcite $\theta = 64° 2'$.

The form $-\frac{10}{3}$ P $\frac{10}{7}$, or $-\frac{4}{3}$ $R^{\frac{5}{2}}$ Naumann; $\bar{14}$ 16 7 Miller; $d^{\frac{1}{16}}\, d^{\frac{1}{7}}\, b^{\frac{1}{14}}$ Brooke and Levy. $\phi = 17° 0'$, in Quartz $\theta = 75° 7'$.

The form $-\frac{3}{5}$ P $\frac{3}{2}$, or $-\frac{1}{5}$ R^3 Naumann; 0 2 3 Miller; $b^{\frac{3}{2}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 27° 34'$.

The form $\frac{3}{4}$ P $\frac{3}{2}$, or $\frac{1}{4}$ R^3 Naumann; 3 1 0 Miller; b^3 Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 33° 8'$, Phenakite $\theta = 26° 45'$, Proustite $\theta = 31° 32'$, and Pyrargyrite $\theta = 31° 2'$.

The form $\frac{6}{5}$ P $\frac{3}{2}$, or $\frac{2}{5}$ R^3 Naumann; 5 1 $\bar{1}$ Miller; e_5 Brooke and Levy. $\phi = 19° 6'$, in Corundum $\theta = 59° 1'$, Hematite $\theta = 58° 57'$, and Pyrargyrite $\theta = 43° 55'$.

The form $\frac{3}{2}$ P $\frac{3}{2}$, or $-\frac{1}{2}$ R^3 Naumann; $\bar{1}$ 1 2 Miller; e_2 Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 52° 33'$, Dioptase $\theta = 58° 13'$, Hematite $\theta = 64° 17'$, Phenakite $\theta = 45° 14'$, Pyrargyrite 50° 17′, and Tourmaline $\theta = 34° 22'$.

The form $\frac{15}{8}$ P $\frac{3}{2}$, or $\frac{5}{8}$ R^3 Naumann; 11 1 $\bar{4}$ Miller; $d^1\, d^{\frac{1}{11}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 19° 6'$, in Pyrargyrite $\theta = 56° 24'$.

The form $-\frac{12}{5}$ P $\frac{3}{2}$, or $-\frac{4}{5}$ R^3 Naumann; $\bar{5}$ 3 7 Miller; $d^{\frac{1}{3}}\, d^{\frac{1}{7}}\, b^{\frac{1}{5}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 64° 25'$.

The form 3 P $\frac{3}{2}$, or R^3 Naumann; 2 0 $\bar{1}$ Miller; d^2 Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 69° 2'$, Chalybite $\theta = 58° 35'$, Dolomite $\theta = 68° 32'$, Eudialyte $\theta = 81° 11'$, Hematite $\theta = 76° 28'$, Phenakite $\theta = 63° 38'$, Proustite $\theta = 67° 50'$, Pyrargyrite $\theta = 67° 27'$, and Tourmaline $\theta = 53° 49'$. Calcite has an imperfect cleavage parallel to this form.

The form -3 P $\frac{3}{2}$, or $-R^3$ Naumann; $\bar{4}$ 2 5 Miller; $d^{\frac{1}{2}}\, d^{\frac{1}{5}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 69° 2'$ and Quartz $\theta = 73° 26'$.

The form $\frac{24}{5}$ P $\frac{3}{2}$, or $\frac{8}{5}$ R^3 Naumann; 15 $\bar{1}$ $\bar{9}$ Miller; $d^1\, d^{\frac{1}{9}}\, b^{\frac{1}{15}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 76° 32'$.

The form -6 P $\frac{3}{2}$, or -2 R^3 Naumann; $\bar{3}$ 1 3 Miller; $e_{\frac{1}{3}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 79° 9'$, Hematite $\theta = 83° 8'$, and Pyrargyrite $\theta = 78° 16'$.

The form $\frac{13}{3}$ P $\frac{13}{7}$, or $R^{\frac{13}{3}}$ Naumann; 7 0 $\bar{4}$ Miller; $d^{\frac{7}{4}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 72° 30$.

The form -2 P $\frac{8}{5}$, or $-\frac{1}{8}$ R^4 Naumann; $\bar{3}$ 2 5 Miller; $d^{\frac{1}{2}}\, d^{\frac{1}{5}}\, b^{\frac{1}{3}}$ Brooke and Levy. $\phi = 19° 6'$, in Calcite $\theta = 59° 55'$.

The form $-\frac{8}{3}$ P $\frac{8}{5}$, or $-\frac{2}{3}$ R^4 Naumann; $\bar{10}$ 14 5 Miller; $d^{\frac{1}{14}}\, d^{\frac{1}{5}}\, b^{\frac{1}{10}}$ Brooke and Levy. $\phi = 21° 47'$, in Quartz $\theta = 71° 21'$.

The form 4 P $\frac{8}{5}$, or R^4 Naumann; 5 0 $\bar{3}$ Miller; $d^{\frac{5}{3}}$ Brooke and Levy. $\phi = 21° 47'$, in Calcite $\theta = 73° 51$.

The form $\frac{5}{4}$ P $\frac{5}{3}$, or $\frac{1}{4}$ R^5 Naumann; $4\ 1\ \bar{1}$ Miller; e_4 Brooke and Levy. $\phi = 23° 25'$, in Corundum $\theta = 59° 45'$, Emerald $\theta = 47° 24'$, and Hematite $\theta = 59° 41'$.

The form $-\frac{5}{4}$ P $\frac{5}{3}$, or $-\frac{1}{4}$ R^5 Naumann; $5\ 11\ \bar{4}$ Miller; $d^{\frac{1}{5}}\, d^{\frac{1}{11}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 23° 25'$, in Emerald $\theta = 47° 24'$.

The form $-\frac{10}{7}$ P $\frac{5}{3}$, or $-\frac{2}{7}$ R^5 Naumann; $\bar{3}\ 3\ 7$ Miller; $e_{\frac{7}{3}}$ Brooke and Levy. $\phi = 23° 25'$, in Calcite $\theta = 50° 52'$.

The form $\frac{4}{3}$ P $\frac{5}{3}$, or $\frac{1}{3}$ R^5 Naumann; $\bar{4}\ 11\ 2$ Miller; $d^{\frac{1}{2}}\, d^{\frac{1}{11}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 23° 25'$, in Quartz $\theta = 61° 33'$.

The form $-\frac{5}{2}$ P $\frac{5}{3}$, or $-\frac{1}{2}$ R^5 Naumann; $\bar{2}\ 1\ 3$ Miller; $d^1\, d^{\frac{1}{3}}\, b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 23° 25'$, in Calcite $\theta = 65° 4'$, and Hematite $\theta = 73° 42'$.

The form 5 P $\frac{5}{3}$, or R^5 Naumann; $3\ 0\ \bar{2}$ Miller; $d^{\frac{3}{2}}$ Brooke and Levy. $\phi = 23° 25'$, in Calcite $\theta = 76° 55'$, Emerald $\theta = 77° 3'$, Proustite $\theta = 76° 7'$, Pyrargyrite $\theta = 75° 51'$, and Tourmaline $\theta = 66° 4'$.

The form -5 P $\frac{5}{3}$, or $-$ R^5 Naumann; $2\ 8\ \bar{7}$ Miller; $d^{\frac{1}{2}}\, d^{\frac{1}{8}}\, b^{\frac{1}{7}}$ Brooke and Levy. $\phi = 23° 25'$, in Emerald $\theta = 77° 3'$.

The form $-\frac{11}{5}$ P $\frac{12}{7}$, or $-\frac{2}{5}$ R^6 Naumann; $\overline{14}\ 22\ 7$ Miller; $d^{\frac{1}{22}}\, d^{\frac{1}{7}}\, b^{\frac{1}{14}}$ Brooke and Levy. $\phi = 24° 30'$, in Quartz $\theta = 69° 20'$.

The form $\frac{7}{10}$ P $\frac{7}{4}$ or $\frac{1}{10}$ R^7 Naumann; $7\ 3\ 0$ Miller; $b^{\frac{7}{3}}$ Brooke and Levy. $\phi = 25° 17'$, in Calcite $\theta = 37° 37'$.

The form $-\frac{7}{5}$ P $\frac{7}{4}$, or $-\frac{1}{5}$ R^7 Naumann; $\bar{2}\ 2\ 5$ Miller; $e_{\frac{5}{2}}$ Brooke and Levy. $\phi = 25° 17'$, in Calcite $\theta = 57° 1'$.

The form $\frac{7}{4}$ P $\frac{7}{4}$, or $\frac{1}{4}$ R^7 Naumann; $5\ 1\ \bar{2}$ Miller; $d^1\, d^{\frac{1}{5}}\, b^{\frac{1}{2}}$ Brooke and Levy. $\phi = 25° 17'$, in Pyrargyrite $\theta = 54° 9'$.

The form 7 P $\frac{7}{4}$, or R^7 Naumann; $4\ 0\ \bar{3}$ Miller; $d^{\frac{4}{3}}$ Brooke and Levy. $\phi = 25° 17'$, in Calcite $\theta = 82° 36'$, and Pyrargyrite $\theta = 79° 46'$.

The form $-\frac{9}{4}$ P $\frac{9}{5}$, or $-\frac{1}{2}$ R^9 Naumann; $5\ 1\ \bar{4}$ Miller; $d^1\, d^{\frac{1}{5}}\, b^{\frac{1}{4}}$ Brooke and Levy. $\phi = 26° 20'$, in Dolomite $\theta = 74° 58'$.

The form 9 P $\frac{9}{5}$, or R^9 Naumann; $5\ 0\ \bar{4}$ Miller; $d^{\frac{5}{4}}$ Brooke and Levy. $\phi = 26° 20'$, in Calcite $\theta = 82° 36'$.

The form 11 P $\frac{11}{6}$, or R^{11} Naumann; $6\ 0\ \bar{5}$ Miller; $d^{\frac{6}{5}}$ Brooke and Levy. $\phi = 27° 0'$, in Calcite $\theta = 83° 56'$.

The form 12 P $\frac{24}{13}$, or R^{12} Naumann; $13\ 0\ \overline{11}$ Miller; $d^{\frac{13}{11}}$ Brooke and Levy. $\phi = 27° 15'$, in Calcite $\theta = 84° 26'$.

Other forms derived from the Double Twelve-faced Pyramid.—If the faces of the upper pyramid, whose poles are marked by T_1 V_1 T_3 V_3 T_5 and V_5 (Fig. 255), are produced to meet the corresponding faces of the lower pyramid; the resulting form will be a *double six-faced pyramid* similar in form, but different in position to the double six-faced pyramids derived from those of the first and second order. The remaining twelve faces being produced to meet each other will produce a similar double *six-faced pyramid.*

From these *double six-faced pyramids, rhomboids and double three-faced pyramids* may be produced by producing half their faces to meet each other.

If the alternate faces of the upper pyramid, whose poles are T_1 V_1 T_3 V_3 T_5 and V_5

(Fig. 255), be produced to meet the faces of the lower pyramid corresponding to V_6 T_2 V_2 T_4 V_4 and T_6, the resulting figure will be a double *six-faced trapezohedron.*

Half the faces of this trapezohedron, namely those corresponding to T_1 T_3 and T_5, for the upper pyramid, and T_2 T_4 and T_6 for the lower, when produced to meet will form a *double three-faced trapezohedron.* This figure may also be formed by producing the alternate faces of the upper part of the scalenohedron to meet the alternate faces of the lower scalenohedron which do not correspond to them.

The double three-faced trapezohedron may be regarded as a *hemihedral* form of either the *double six-faced trapezohedron* or the *hexagonal scalenohedron*, and consequently a *tetartohedral form* of the double twelve-faced pyramid. The forms of quartz given under the head of scalenohedrons, generally present in their combinations this species of the *tetartohedral forms.*

PRINCIPAL COMBINATIONS OF THE RHOMBOHEDRAL SYSTEM.

Fig. 286. Combination of the *double six-faced pyramid of the second order*, with the *hexagonal prism of the second order.* *a*, faces of the negative rhomboid — R Naumann,

Fig. 286.

Fig. 287.

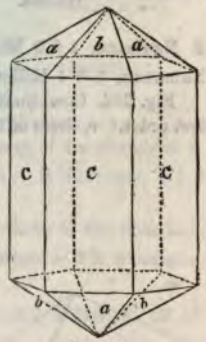


Fig. 288.

$\bar{1}$ 2 2 Miller, $e^{\frac{1}{2}}$ Brooke and Levy. *b*, faces of the negative rhomboid R Naumann, 1 0 0 Miller, and P Brooke and Levy. *c*, faces of the hexagonal prism of the second order, ∞ P Naumann, 2 $\bar{1}$ $\bar{1}$ Miller, and e^2 Brooke and Levy.

Fig. 287. Combination of the *double six-faced pyramid of the second order* with the *hexagonal prism of the first order.* *a*, faces of the *negative rhomboid.* *b*, faces of the *positive rhomboid.* *e*, faces of the hexagonal prism of the first order, ∞ P 2 Naumann, 0 1 $\bar{1}$ Miller, and d^1 Brooke and Levy.

Fig. 288. Combination of the *hexagonal prism of the second order* with the *double six-faced pyramid of the second order.* *a*, faces of negative rhomboid. *b*, faces of positive rhomboid. *c*, faces of hexagonal prism of the second order.

Fig. 289. Combination of two positive rhomboids. *r*, faces of the rhomboid whose symbols are R Naumann, 1 0 0 Miller, and P Brooke and Levy. *s*, faces of the rhomboid whose symbols are 2 R Naumann, 5 $\bar{1}$ $\bar{1}$ Miller, e^5 Brooke and Levy.

Fig. 290. Combination of a positive and negative rhomboid. *r*, faces of the rhomboid 2 R Naumann, 5 $\bar{1}$ $\bar{1}$ Miller, e^5 Brooke and Levy. *s*, faces of the rhomboid — R Naumann, $\bar{1}$ 2 2 Miller, $e^{\frac{1}{2}}$ Brooke and Levy.

Fig. 291. Combination of a scalenohedron and rhomboid. *r*, faces of the rhombo

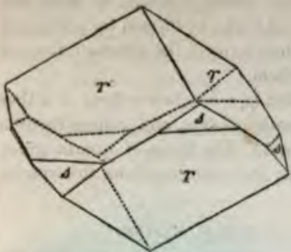


Fig. 289.

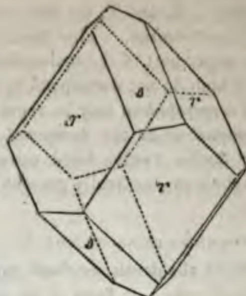


Fig. 290.

Fig. 291.

R Naumann, 1 0 0 Miller, P Brooke and Levy. *t*, faces of the scalenohedron, I
Naumann, 2 0 $\bar{1}$ Miller, d^2 Brooke and Levy.

Fig. 292. Combination of the positive rhomboid with the hexagonal prism of th
first order. *r*, faces of the rhomboid. *e*, faces of the prism.

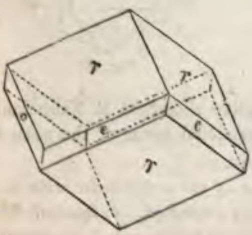


Fig. 292.

Fig. 293.

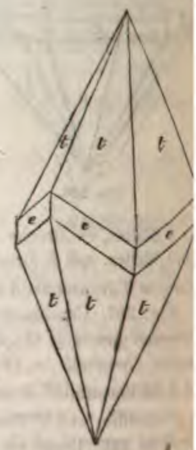


Fig. 294.

Fig. 293. Combination of a positive scalenohedron with the hexagonal prism of th
second order. *t*, faces of scalenohedron. *e*, faces of prism.

Fig. 294. Combination of a positive scalenohedron with the hexagonal prism of th
first order. *t*, faces of scalenohedron. *e*, faces of prism.

Fig. 295. Combination of hexagonal prism of the second order with positiv
rhomboid. *e*, faces of prism. R, faces of rhomboid.

Fig. 296. Combination of hexagonal prism of the first order with a positive rhomboid. *e*, faces of prism. R, faces of rhomboid.

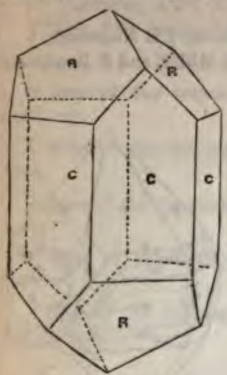


Fig. 295.

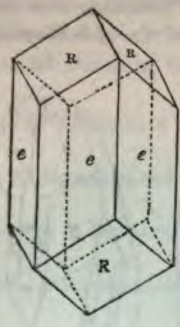


Fig. 296.

Fig. 297.

Fig. 297. Complex combination of forms in a crystal of Beryl.

m, face of basal pinacoid, O P Naumann, 1 1 1 Miller, a^1 Brooke and Levy.

P, faces of the double six-faced pyramid P Naumann; or faces of the rhomboid R Naumann, 1 0 0 Miller, P Brooke and Levy, and the rhomboid — R Naumann, $\bar{1}$ 2 2 Miller, $e^{\frac{1}{2}}$ Brooke and Levy.

u, faces of the double six-faced pyramid 2 P Naumann; or faces of the rhomboid 2 R Naumann, 5 $\bar{1}$ $\bar{1}$ Miller, e^5 Brooke and Levy, and of the rhomboid — 2 R Naumann, 1 1 $\bar{1}$ Miller, e^1 Brooke and Levy.

s, faces of the double six-faced pyramid 2 P 2 Naumann, 1 4 $\bar{2}$ Miller, d^1 $d^{\frac{1}{4}}$ $b^{\frac{1}{2}}$ Brooke and Levy.

v, faces of the scalenohedron R^3 Naumann, 2 0 $\bar{1}$ Miller, d^2 Brooke and Levy.

x, faces of the scalenohedron — R^3 Naumann, $\bar{4}$ 2 5 Miller, $d^{\frac{1}{2}}$ $d^{\frac{1}{5}}$ $b^{\frac{1}{4}}$ Brooke and Levy.

x and *v*, together, giving the faces of the double twelve-faced pyramid 3 P $\frac{3}{2}$ Naumann.

M, faces of the hexagonal prism ∞ P Naumann, 2 $\bar{1}$ $\bar{1}$ Miller, e^2 Brooke and Levy.

Fig. 298. Complex combination of forms in a crystal of Apatite.

P, face of basal pinacoid, O P Naumann, 1 1 1 Miller, a^1 Brooke and Levy.

M, faces of the hexagonal prisms, ∞ P Naumann, 2 $\bar{1}$ $\bar{1}$ Miller, e^2 Brooke and Levy.

e, faces of the hexagonal prism, ∞ P 2 Naumann, 0 1 $\bar{1}$ Miller, d^1 Brooke and Levy.

a, faces of the pyramid, P 2 Naumann, 5 2 $\bar{1}$ Miller, $d^{\frac{1}{5}}$ $d^{\frac{1}{2}}$ b^1 Brooke and Levy.

s, faces of the pyramid, 2 P 2 Naumann, 1 4 $\bar{2}$ Miller, d^1 $d^{\frac{1}{4}}$ $b^{\frac{1}{2}}$ Brooke and Levy.

d, faces of the pyramid, 4 P 2 Naumann, 1 7 $\bar{5}$ Miller, d^1 $d^{\frac{1}{7}}$ $b^{\frac{1}{5}}$ Brooke and Levy.

x, faces of the pyramid, P Naumann; or of the rhomboids, R Naumann, 1 0 0 Miller, P Brooke and Levy; and — R Naumann, $\bar{1}$ 2 2 Miller, $e^{\frac{1}{2}}$ Brooke and Levy.

z, faces of the pyramid, 2 P Naumann; or of the rhomboids, 2 R Naumann, 5 $\bar{1}$ $\bar{1}$ Miller, e^5 Brooke and Levy; and of — 2 R Naumann, $\bar{1}$ 1 1 Miller, e^1 Brooke and Levy.

r, faces of the pyramid, $\frac{1}{2}$ P Naumann; or of the rhomboids, $\frac{1}{2}$ R Naumann, 4 1 1 Miller, a^4 Brooke and Levy; and of — $\frac{1}{2}$ R Naumann, 0 1 1 Miller, and b^1 Brooke and Levy.

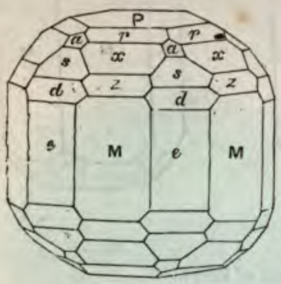


Fig. 298.

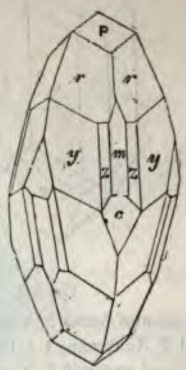


Fig. 299.

Fig. 300.

Fig. 299. Complex combination of forms in a crystal of calcareous spar.

P, faces of the rhomboid, R Naumann, 1 0 0 Miller, P Brooke and Levy.

m, faces of the rhomboid, 4 R Naumann, 3 $\bar{1}$ $\bar{1}$ Miller, e^3 Brooke and Levy.

y, faces of the scalenohedron, R^5 Naumann, 3 0 $\bar{2}$ Miller, $d^{\frac{3}{2}}$ Brooke and Levy.

r, faces of the scalenohedron, R^3 Naumann, 2 0 $\bar{1}$ Miller, d^2 Brooke and Levy.

z, faces of the scalenohedron, $\frac{8}{5}$ R^3 Naumann, 15 $\bar{1}$ $\bar{9}$ Miller, d^1 $d^{\frac{1}{5}}$ $b^{\frac{1}{15}}$ Brooke and Levy.

c, faces of the hexagonal prism, ∞ P Naumann, 2 $\bar{1}$ $\bar{1}$ Miller; e^2 Brooke and Levy.

Fig. 300. Complex combination of forms in a crystal of quartz.

P, faces of the pyramid, P Naumann; or of the rhomboids, R Naumann, 1 0 0 Miller, P Brooke and Levy; and — R Naumann, $\bar{1}$ 2 2 Miller, $e^{\frac{1}{2}}$ Brooke and Levy.

b, faces of the pyramid, $\frac{4}{3}$ P Naumann; or of the rhomboids, $\frac{4}{3}$ R Naumann, 13 $\bar{2}$ $\bar{2}$ Miller, $e^{\frac{13}{2}}$ Brooke and Levy; and — $\frac{4}{3}$ R Naumann, 7 $\bar{8}$ $\bar{8}$ Miller, $e^{\frac{1}{8}}$ Brooke and Levy.

m faces of the pyramid, 3 P Naumann; or of the rhomboids, 3 R Naumann, 7 $\bar{2}$ $\bar{2}$ Miller, $e^{\frac{7}{2}}$ Brooke and Levy; and — 3 R Naumann, $\bar{5}$ 4 4 Miller, $e^{\frac{5}{4}}$ Brooke and Levy.

a faces of the pyramid, 4 P Naumann; or of the rhomboids, 4 R Naumann, 3 $\bar{1}$ $\bar{1}$ Miller, e^3 Brooke and Levy, and — 4 R Naumann, $\bar{7}$ 5 5 Miller, $e^{\frac{7}{5}}$ Brooke and Levy.

s faces of a double three-faced pyramid derived from the double six-faced pyramid, 2 P 2 Naumann, 1 4 $\bar{2}$ Miller, d^1 $d^{\frac{1}{4}}$ $b^{\frac{1}{2}}$ Brooke and Levy.

o faces of the double three-faced trapezohedron derived from the scalenohedron $-R^3$ Naumann, $\bar{4}\ 2\ 5$ Miller, $d^{\frac{1}{2}}\ d^{\frac{1}{5}}\ b^{\frac{1}{4}}$ Brooke and Levy.

x faces of the double three-faced trapezohedron derived from the scalenohedron $2\ R^2$ Naumann, $8\ \bar{1}\ \bar{4}$ Miller, $d^1\ d^{\frac{1}{4}}\ b^{\frac{1}{8}}$ Brooke and Levy.

g faces of the trapezohedron $3\ R^{\frac{5}{3}}$ Naumann, $10\ \bar{2}\ \bar{5}$ Miller, $d^{\frac{1}{2}}\ d^{\frac{1}{5}}\ b^{\frac{1}{10}}$ Brooke and Levy.

u faces of the trapezohedron $4\ R^{\frac{3}{2}}$ Naumann, $4\ \bar{1}\ \bar{2}$ Miller, $d^1\ d^{\frac{1}{2}}\ b^{\frac{1}{4}}$ Brooke and Levy.

v faces of the trapezohedron $6\ R^{\frac{4}{3}}$ Naumann, $16\ \bar{5}\ \bar{8}$ Miller, $d^{\frac{1}{5}}\ d^{\frac{1}{8}}\ b^{\frac{1}{16}}$ Brooke and Levy.

r faces of the hexagonal prism ∞ P Naumann, $2\ \bar{1}\ \bar{1}$ Miller, e^2 Brooke and Levy.

d faces of the dihexagonal prism $\infty\ P\ \frac{3}{2}$ Naumann, $\bar{5}\ \bar{1}\ 4$ Miller, $d^1\ d^{\frac{1}{4}}\ b^{\frac{1}{5}}$ Brooke and Levy.

FOURTH SYSTEM—PRISMATIC OR RHOMBIC.

This system is called the *Prismatic* or *Rhombic*, as its forms may be derived either from the prism, or octahedron on a rhombic base. It has also been called the *orthotype* and the *one and one axial* system.

The ***holohedral forms*** of this system are ***a right prism on a rectangular base***, three kinds or orders of ***right prisms on a rhombic base***, and the ***double four-faced pyramid on a rhombic base***. The ***hemihedral form*** is the ***rhombic sphenoid*** derived from the double four-faced pyramid.

Alphabetical list of Minerals belonging to the Prismatic System, with the Angular Elements from which their Typical Forms and Axes may be derived.

Aeschynite . .	26° 20′; 33° 46′
Alstonite . .	30° 34′; 36° 27′
Amblygonite . .	Unknown.
Andalusite . .	44° 38′; 35° 5′
Anglesite (sulphate of lead) .	38° 11′; 52° 16′
Antimonsilber . .	30° 0′; 33° 53′
Antimonite . .	44° 37′; 45° 36′
Aragonite (carbonate of lime)	31° 55′; 35° 47′
Baryte (sulphate of barytes)	39° 10′; 52° 42′
Bismuthine . .	44° 30′; Unkn.
Bournonite . .	43° 10′; 41° 53′
Brochantite . .	37° 55′; 14° 4′
Brookite . . .	40° 5′; 43° 22′
Caledonite (cupreous sulphato-carbonate of lead) .	42° 30′; 54° 31′
Celestine (sulphate of strontian)	37° 59′; 52° 4′
Cerussite (carbonate of lead)	31° 23′; 35° 52′
Childrenite . .	34° 3′; 32° 44′
Chloanthite . .	Unknown.
Chrysoberyl . .	25° 11′; 30° 7′
Comptonite . .	Unknown.
Cordierite . .	30° 25′; 29° 11′
Cotunnite . .	40° 7′; 26° 38′
Cryolite . . .	Unknown.
Datholite . . .	38° 22′; 26° 34′
Diaspore . . .	43° 4′; 30° 39′
Dufrenite (phosphate of iron)	Unknown.
Epistilbite . .	22° 25′; 16° 10′
Epsomite (sulphate of magnesia)	44° 43′; 29° 43′
Euchroite . .	31° 20′; 46° 4′
Eudnophite . .	Unknown.
Fayalite . . .	42° 40′; 49° 11′
Fluellite . . .	37° 35′; 61° 58′
Gadolonite . .	30° 15′; 50° 30′
Glaserite (sulphate of potash)	29° 48′; 36° 44′
Glaucodote . .	Unknown.
Goslarite (sulphate of zinc) .	44° 39′; 29° 58′
Göthite . . .	42° 34′; 31° 15′
Haidingerite . .	40° 0′; 26° 31′
Harmotome . .	44° 7′; 34° 47′
Herderite . .	32° 3′; 23° 1′
Ilvaite . . .	34° 24′; 24° 31′
Jamesonite . .	39° 20′; Unkn.
Karstenite (anhydrons sulphate of lime) . .	41° 42′; 44° 25′
Leadhillite (sulphato-carbonate of lead) . .	29° 50′; 51° 37′
Libethenite (phosphate of copper)	43° 50′; 35° 4′
Liroconite (octahedral arseniate of copper) . .	30° 20′; 38° 20′
Loganite . . .	Unknown.
Lölingite . . .	28° 47′; 41° 10′
Manganite . .	40° 10′; 28° 35′
Marcasite . .	36° 57′; 49° 50′
Mascagnine (sulph. of ammonia)	29° 26′; 36° 10′
Mendipite . .	Unknown.
Mengite . . .	21° 50′; 19° 14′
Mesotype . . .	44° 30′; 19° 24′
Mispickel . .	34° 3′; 49° 56′
Monticellite . .	41° 5′; 48° 46′

Niobite . . .	39° 40′; 41° 16′	Staurolite . .	25° 20′; 34° 2[illegible]
Nitre (nitrate of potash) .	30° 35′; 35° 1′	Stephanite . .	32° 10′; 34° 26′
Olivenite (right prismatic arseniate of copper) .	43° 45′; 34° 35′	Sternbergite . .	30° 15′; 40° 0′
Olivine . . .	42° 58′; 49° 33′	Stilbite . . .	42° 52′; 37° 4′
Orpiment . .	30° 5′; 33° 0′	Strontianite (carbonate of strontian) . .	31° 21′; 35° 54′
Patrinite . . .	Unknown.	Stromeyerite . .	30° 12′; 44° 8′
Phillipsite . .	44° 24′; 34° 59′	Struvite . . .	28° 35′; 31° 34′
Picrosmine . .	26° 34′; 16° 48′	Sulphur . . .	39° 1′; 62° 12′
Polianite . . .	43° 34′; 31° 0′	Sylvanite . . .	34° 36′; 31° 26′
Polyhalite . .	Unknown.	Tantalite . . .	39° 14′; 33° 6′
Polykrase . .	20° 0′; 18° 53′	Thenardite (sulphate of soda)	25° 19′; 28° 50′
Polymignyte . .	35° 7′; 31° 24′	Thermonatrite (prismatic carbonate of soda) .	20° 1′; 48° 5′
Porzellanspath . .	Unknown.	Topaz . . .	27° 50′; 43° 31′
Prehnite . . .	40° 2′; 40° 9′	Triplite (phosphate of manganese) . .	Unknown.
Pyrolusite . .	43° 10′; 20° 0′	Tyrolite . . .	Unknown.
Pyrophyllite . .	Unknown.	Valentinite . .	21° 31′; 54° 44′
Redruthite . .	30° 12′; 44° 8′	Wavellite . .	26° 47′; 20° 34′
Remolinite (muriate of copper)	33° 50′; 37° 10′	Witherite (carbonate of barytes)	30° 45′; 36° 33′
Roselite . . .	23° 36′; 31° 51′	Wölchite . . .	Unknown.
Samarskite . .	39° 40′; 41° 16′	Wolfram (tungstate of iron) .	39° 7′; 40° 46′
Schulzite . .	Unknown.	Wolfsbergite . .	22° 24′; Unkn.
Scorodite (martial arseniate of copper) . .	40° 59′; 43° 39′	Zinckenite . .	29° 40′; 8° 30′
Smithsonite (siliceous oxide of zinc) . .	38° 3′; 25° 46′	Zwiselite . . .	Unknown.

The Right Rectangular Prism.—The right rectangular prism, or the right prism on a rectangular base, is a solid form bounded by six faces; these faces are all rectangular parallelograms, and equal to each other in pairs; thus (Fig. 301), the face B_1 B_5 B_8 B_4 is equal to the face B_2 B_6 B_7 B_3, B_1 B_2 B_6 B_5 to B_4 B_3 B_7 B_8, and B_1 B_2 B_3 B_4 to B_5 B_6 B_7 B_8.

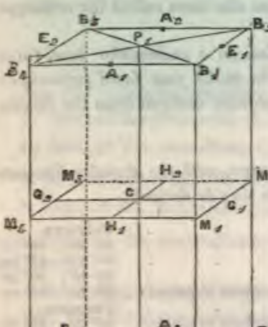


Fig. 301.

Modern writers consider this prism as a combination of three open forms, each form consisting of a pair of parallel faces; the bases of the prism are then called the *basal pinacoids*, the wider sides *macro-pinacoids*, and the narrower *brachy-pinacoids*.

Axes of the Right Rectangular Prism and the Prismatic System.—Join B_1 B_3 and B_2 B_4, cutting each other in P_1, also B_6 B_8 and B_5 B_7, cutting each other in P_2. Bisect B_1 B_5, B_2 B_6, B_3 B_7, and B_4 B_8 in the points M_1, M_2, M_3 and M_4. Join M_1 M_2, M_2 M_3, M_3 M_4, and M_4 M_1. Bisect M_1 M_2 and M_3 M_4 in the points G_1 and G_2, and M_1 M_4 and M_2 M_3 in H_1 and H_2. Join P_1 P_2, H_1 H_2, and G_1 G_2, cutting each other in C. The three lines P_1 P_2, H_1 H_2, and G_1 G_2, which are at right angles to each other, are the *axes* of the *rectangular prism*, and also of the *prismatic system*. P_1 P_2 is called the principal axis, and H_1 H_2 and G_1 G_2 the secondary axes.

Parameters.—The semi-axes CP_1, CG_1, and CH_1, are the *parameters* of the prismatic system; the length of CG_1 is perfectly arbitrary, but its length once chosen, the lengths of CP_1 and CH_1 depend upon the angular elements already given for each mineral belonging to the system.

To determine CP_1 and CH_1 draw CG (Fig. 302) of any convenient length, as the *arbitrary unit* of the system of axes.

Draw CP perpendicular to GC. Let α be the angle given in the first, and β the angle given in the second column of the angular elements.

Draw HG making the angle α, and PG making the angle β, with GC.

Let H and P be the points where GH and GP meet the perpendicular CP.

For Aeschynite, the angle CGH is 26° 20′, and the angle CGP 33° 46′; for Alstonite, the angle CGH is 30° 34′, and the angle CGP 36° 28′; and so on for the other substances belonging to the prismatic system.

The lines CG, CH, and CP, thus determined, are the parameters of the prismatic system; it appears, therefore, that the *axes* of this system are *rectangular*, and its three *parameters* all *unequal* to each other.

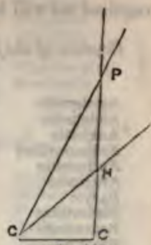


Fig. 302.

To draw the Right Rectangular Prism.—Draw B_8 B_5 (Fig. 301) equal to twice GC (Fig. 302). Through B_8 draw B_8 B_7, making an angle of about 30°, with B_8 B_5.

Make B_8 B_7 equal to CH (Fig. 302). Through B_5 draw B_5 B_6 equal and parallel to B_8 B_7; join B_7 B_6.

Through B_8 draw B_8 B_4 perpendicular to B_8 B_5 and equal to twice CP (Fig. 302).

Through B_5, B_6 and B_7 draw B_5 B_1, B_6 B_2, and B_7 B_3 parallel and equal to B_8 B_4.

Join the points B_1 B_2 B_3 and B_4, and the prism will be represented in perspective.

Symbols.—Each face of the rectangular prism cuts one of the three axes at a distance from C (Fig. 301), the centre of the axes, equal to the length of one of the parameters, and is parallel to the other two axes.

The two *basal pinacoids*, or extremities of the prism B_1 B_2 B_3 B_4 and B_5 B_6 B_7 B_8, cut the axis P_1 P_2 in the points P_1 and P_2, and are parallel to the axes G_1 G_2 and H_1 H_2. The symbol which represents the relation of these faces of the prism to the axes is ∞ ∞ 1.

Naumann's symbol is 0P; Miller's 0 0 1; Brooke and Levy's modification of Haüy is P, when they regard the right rhombic prism as the primitive form of the crystal.

The two *macro-pinacoids*, or broader sides of the prism, B_1 B_4 B_8 B_5 and B_2 B_3 B_7 B_6 cut the axis H_1 H_2 in the points H_1 and H_2, and are parallel to the axes P_1 P_2 and G_1 G_2. The symbol representing this relation is ∞ 1 ∞.

Naumann's symbol is $\infty\ \bar{P}\ \infty$, Miller's 0 1 0, Brooke and Levy's H.

The two *brachy-pinacoids*, or narrower sides of the prism, B_1 B_2 B_6 B_5 and B_4 B_3 B_7 B_8, cut the axis G_1 G_2 in the points G_1 and G_2, and are parallel to the axes H_1 H_2 and P_1 P_2. The symbol representing this relation is 1 ∞ ∞. Naumann's symbol is $\infty\ \breve{P}\ \infty$, Miller's 1 0 0, Brooke and Levy's G.


Fig. 303.

To describe a Net for the Right Rectangular Prism. — Take two parallelograms equal to B_1 B_4 B_8 B_5 (Fig. 301), to represent the *macro-pinacoids*, two others equal in length to these, but with a breadth equal to twice CH (Fig. 302) for the *brachy-pinacoids*, and two parallelograms each twice GC (Fig. 302) in breadth, and twice CH in length for the *basal-pinacoids*; arrange these six rectangular parallelograms as in Fig. 303, and the required net will be constructed.

Crystals of the following minerals have Faces parallel to the Basal Pinacoids $\infty \infty 1$.

0 P Naumann, 0 0 1 Miller, P Brooke and Levy.

Aeschynite	Comptonite	Ilvaite	Olivine	Strontianite
Andalusite	Cordierite	Jamesonite	Polyhalite	Stromeyerite
Anglesite	Cotunnite	Karstenite	Polymignite	Sulphur
Antimonsilber	Cryolite	Leadhillite	Prehnite	Sylvanite
Antimonite	Datholite	Loganite	Pyrolusite	Tantalite
Aragonite	Diaspore	Löllingite	Redruthite	Thenardite
Baryte	Euchroite	Manganite	Roselite	Thermonatrite
Bismuthine	Eudnophite	Marcasite	Scorodite	Topaz
Bournonite	Fayalite	Mascagnine	Smithsonite	Tyrolite
Brookite	Fluellite	Mendipite	Staurolite	Witherite
Caledonite	Gadolinite	Mispickel	Stephanite	Wölchite
Celestine	Glaserite	Niobite	Sternbergite	Wolfram
Cerussite	Herderite	Nitre	Stilbite	Wolfsbergite
Chrysoberyl				

The following present Cleavages parallel to this form.

Anglesite	Chrysoberyl	Jamesonite	Mascagnine	*Sternbergite*
Antimonsilber	Comptonite	*Karstenite*	Mispickel	Tantalite
Antimonite	*Cryolite*	*Leadhillite*	Niobite	*Thenardite*
Baryte	*Eudnophite*	*Loganite*	*Prehnite*	*Topaz*
Bournonite	*Fayalite*	Löllingite	*Roselite*	*Tyrolite*
Caledonite	Glaserite	Manganite	Smithsonite	Wolfsbergite
Celestine				

Minerals whose Crystals present Faces parallel to the Macro-pinacoids $\infty 1 \infty$.

$\infty \bar{P} \infty$ Naumann, 0 1 0 Miller, H Brooke and Levy.

Aeschynite	Comptonite	Haidingerite	Nitre	Remolinite
Andalusite	Cordierite	Harmotome	Olivenite	Schalzite
Anglesite	Cotunnite	Herderite	Olivine	Scorodite
Antimonsilber	Cryolite	Ilvaite	Orpiment	Smithsonite
Antimonite	Datholite	Jamesonite	Phillipsite	Stephanite
Aragonite	Epsomite	Karstenite	Picrosmine	Stilbite
Baryte	Eudnophite	Libethenite	Polianite	Struvite
Bismuthine	Fayalite	Loganite	Polykrase	Sulphur
Bournonite	Gadolinite	Manganite	Polymignite	Sylvanite
Brookite	Glaserite	Mascagnine	Prehnite	Tantalite
Celestine	Goslarite	Mendipite	Pyrolusite	Wölchite
Cerussite	Göthite	Niobite	Redruthite	Wolfram
Chrysoberyl				

Cleavages parallel to this form occur in the following minerals.

Aeschynite	Chrysoberyl	*Jamesonite*	*Niobite*	*Pyrolusite*
Andalusite	Comptonite	*Karstenite*	Olivine	Scorodite
Antimonite	Cryolyte	Loganite	Orpiment	Stilbite
Baryte	Eudnophite	Manganite	Phillipsite	*Struvite*
Bournonite	Fayalite	Mascagnine	Picrosmine	Tantalite
Celestine	Harmotome	Mendipite	Polymignite	*Wolfram*

Minerals whose Crystals present Faces parallel to the Brachy-pinacoids $1 \infty \infty$

$\infty \breve{P} \infty$ Naumann, 1 0 0 Miller, G Brooke and Levy.

Aeschynite	Bismuthine	Chrysoberyl	Epsomite	Harmotome
Alstonite	Bournonite	Comptonite	Euchroite	Herderite
Andalusite	Brochantite	Cordierite	Eudnophite	Ilvaite
Anglesite	Brookite	Cotunnite	Fayalite	Jamesonite
Antimonsilber	Caledonite	Cryolite	Glaserite	Karstenite
Antimonite	Celestine	Datholite	Goslarite	Leadhillite
Aragonite	Cerussite	Diaspore	Göthite	Libethenite
Baryte	Childrenite	Epistilbite	Haidingerite	Loganite

Manganite	Olivenite	Prehnite	Sternbergite	Topaz
Mascagnine	Olivine	Pyrolusite	Stilbite	Tyrolite
Mendipite	Orpiment	Redruthite	Strontianite	Valentinite
Mengite	Phillipsite	Remolinite	Stromeyerite	Wavellite
Mesotype	Picrosmine	Roselite	Struvite	Witherite
Mispickel	Polianite	Scorodite	Sylvanite	Wölchite
Monticellite	Polyhalite	Smithsonite	Tantalite	Wolfram
Niobite	Polykrase	Staurolite	Thenardite	Wolfsbergite
Nitre	Polymignite	Stephanite	Thermonatrite	Zinckenite

Cleavages parallel to this form occur in the following minerals.

Alstonite	Childrenite	Glaserite	Nitre	Stephanite
Andalusite	Chrysoberyl	*Göthite*	*Olivine*	*Stilbite*
Anglesite	*Comptonite*	*Haidingerite*	*Orpiment*	Strontianite
Antimonite	Cordierite	*Harmotome*	*Phillipsite*	Tantalite
Aragonite	Cryolite	Jamesonite	*Picrosmine*	Thermonatrite
Baryte	Datholite	*Karstenite*	*Polianite*	*Wavellite*
Bournonite	*Diaspore*	Leadhillite	Polymignite	Witherite
Brochantite	*Epistilbite*	*Manganite*	*Pyrolusite*	Wölchite
Brookite	*Epsomite*	*Mascagnine*	*Remolinite*	*Wolfram*
Caledonite	Eudnophite	Mendipite	Scorodite	*Wolfsbergite*
Celestine	Fayalite	*Niobite*	*Staurolite*	

Right Rhombic Prism of the First Order.—The right rhombic prism of the first order, or the *rectangular prism on a rhombic base*, is a solid bounded by six faces, four of which are rectangular parallelograms, such as $A_1 E_2 E_3 A_3$ (Fig. 304); the other two are rhombs. When this prism is considered as an open form, the four rectangular faces only are taken as its faces, the two rhombic faces which inclose it being then regarded as the *basal pinacoids*.

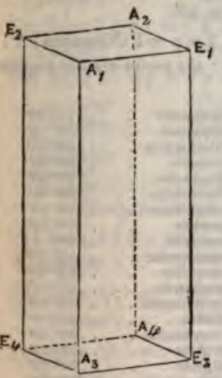


Fig. 304.

To draw the Rhombic Prism of the First Order.—Bisect the edges $B_1\ B_4$, $B_2\ B_3$, $B_8\ B_5$, and $B_6\ B_7$ of the prism (Fig. 301), in the points A_1, A_2, A_3, and A_4; also $B_1\ B_2$, $B_4\ B_3$, $B_5\ B_6$, and $B_8\ B_7$, in E_1, E_2, E_3, and E_4. Prick off the points A_1, A_2, A_3, A_4, E_1, E_2, E_3 and E_4, and join these points, as in Fig. 304, and the prism will be represented.

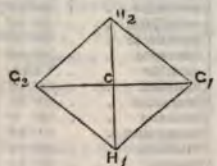


Fig. 305.

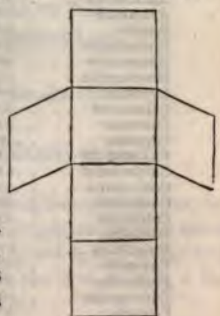


Fig. 306.

Symbols.—Each face of this prism, considered as an open form, cuts two of the axes $G_1\ G_2$ (Fig. 301) and $H_1\ H_2$, at the extremities of their parameters, and is parallel to the third axis $P_1\ P_2$; the symbol representing this property is $1\ 1\ \infty$; Naumann's is ∞ P, Miller's $1\ 1\ \infty$, and Brooke and Levy's M.

To Describe a Net for the Rhombic Prism.—Draw two lines, $G_1\ G_2$ and $H_1\ H_2$ (Fig. 305), cutting each other at right angles in the point C. Make CG_1 and CG_2 each equal CG (Fig. 302), and CH_1, CH_2 equal to CH (Fig. 302).

Join H_1, G_1, H_2 and G_2, as in Fig. 305. Draw two such rhombs, also four equal rectangular parallelograms, their breadths being equal to H_1 G_1, and of any convenient length. Arrange these figures as in Fig. 306, and the net will be described.

Sphere of Projection for the Prismatic System.—To draw a map of the sphere of projection of the prismatic system, with P_1 (Fig. 307) as a centre, and any convenient radius P_1 G_1 describe the circle G_1 H_1 G_2. Let G_1 G_2, and H_1 H_2, be any two diameters drawn perpendicular to each other. Then P_1, representing the north pole of the sphere of projection, is the pole of the upper basal pinacoid ∞ ∞ 1, or 0 P, Naumann; G_1 and G_2 are the poles of the brachy-pinacoids 1 ∞ ∞, or ∞ $\breve{P}$ ∞, Naumann; and H_1 and H_2 are the poles of the macro-pinacoid ∞ 1 ∞, or ∞ $\bar{P}$ ∞, Naumann.

Fig. 307.

Faces parallel to the Rhombic Prism of the First Order, 1 1 ∞; ∞ P *Naumann;* 1 1 0 *Miller;* M *Brooke and Levy; occur in the following minerals: the angles are the longitude of their poles.*

Aeschynite . .	63° 40′	Göthite . . .	47° 26′	Polyhalite . .	57° 30′
Alstonite . .	59° 26′	Haidingerite . .	50° 0′	Polykrase . .	70° 0′
Andalusite . .	45° 22′	Harmotome . .	45° 53′	Polymignite . .	54° 53′
Anglesite . .	51° 49′	Herderite . .	57° 57′	Prehnite . .	49° 58′
Antimonsilber .	60° 0′	Ilvaite . . .	55° 36′	Pyrolusite . .	46° 50′
Antimonite . .	45° 23′	Jamesonite . .	50° 40′	Redruthite . .	59° 48′
Aragonite . .	58° 5′	Karstenite . .	48° 18′	Remolinite . .	56° 10′
Baryte . .	50° 50′	Leadhillite . .	60° 10′	Roselite . .	66° 24′
Bismuthine . .	45° 30′	Libethenite . .	46° 10′	Scorodite . .	49° 1′
Bournonite . .	46° 50′	Liroconite . .	59° 40′	Smithsonite . .	51° 57′
Brochantite . .	52° 5′	Loganite . .	Unkn.	Staurolite . .	64° 40′
Brookite . .	49° 55′	Lolingite . .	61° 13′	Stephanite . .	57° 50′
Caledonite . .	47° 30′	Manganite . .	49° 50′	Sternbergite . .	59° 45′
Celestine . .	52° 1′	Marcasite . .	53° 3′	Stilbite . . .	47° 8′
Cerussite . .	58° 37′	Mascagnine . .	60° 34′	Strontianite . .	58° 40′
Chloanthite . .	62° 0′	Mendipite . .	51° 18′	Struvite . .	61° 25′
Chrysoberyl . .	64° 49′	Mengite . .	68° 10′	Sulphur . .	50° 59′
Comptonite . .	45° 20′	Mesotype . .	45° 30′	Sylvanite . .	55° 24′
Cordierite . .	59° 35′	Mispickel . .	55° 36′	Thenardite . .	64° 41′
Cotunnite . .	49° 53′	Monticellite . .	48° 55′	Topaz . . .	62° 10′
Datholite . .	51° 38′	Niobite . .	50° 20′	Tyrolite . .	Unkn.
Epistilbite . .	67° 35′	Nitre . . .	59° 25′	Valentinite . .	68° 29′
Epsomite . .	45° 17′	Olivenite . .	46° 15′	Wavellite . .	63° 13′
Euchroite . .	58° 40′	Olivine . . .	47° 1′	Witherite . .	59° 15′
Eudnophite . .	60° 0′	Orpiment . .	58° 55′	Wölchite . .	Unkn.
Fayalite . .	47° 20′	Phillipsite . .	45° 36′	Wolfram . .	50° 53′
Gadolonite . .	59° 45′	Picrosmine . .	63° 26′	Wolfsbergite . .	67° 36′
Glaserite . .	60° 12′	Polianite . .	46° 26′	Zinckenite . .	60° 20′
Goslarite . .	45° 21′				

The following minerals present Cleavages parallel to this form.

Alstonite	Brochantite	Jamesonite	Mispickel	*Strontianite*
Andalusite	Caledonite	Leadhillite	Nitre	Sulphur
Anglesite	Celestine	Liroconite	Olivenite	Thenardite
Antimonsilber	Cerussite	*Loganite*	Prehnite	Topaz
Antimonite	Datholite	*Manganite*	*Pyrolusite*	*Valentinite*
Aragonite	Epsomite	Marcasite	Redruthite	*Wavellite*
Baryte	Euchroite	*Mendipite*	*Smithsonite*	*Witherite*
Bismuthine	Glaserite	Mesotype	Staurolite	

Position of the Poles of the Right Rhombic Prism on the Sphere of Projection.—The poles of this prism all lie in the equator, if θ be the angle of longitude for each substance given above; and if (in Fig. 307) $G_1 D_1$, $G_1 D_2$, $G_2 D_3$, and $G_2 D_4$, be each taken equal to θ, D_1, D_2, D_3 and D_4, will represent the four poles of the prism.

Right Rhombic Prisms derived from the Right Rhombic Prism of the First Order by increasing the greater Axis G_1 G_2.—These prisms will be similar, in all respects, to the prism of the first order, from which they are derived, except that CG_1 and CG_2 (Fig. 301) must be taken n times greater than GC (Fig. 302). Making this alteration, the points A_1, A_2, A_3, A_4, E_1, E_2, E_3, and E_4, will give the angular points of the derived prism. Their symbols will be $n\,1\,\infty$, $\infty \bar{P} n$ Naumann, $h\,k\,o$ Miller, $H^{\frac{n+1}{n-1}}$ Brooke and Levy.

Faces parallel to the following forms of these Prisms have been observed in nature; the angle is that of their longitude.

The form $\frac{4}{3}\,1\,\infty$; $\infty \bar{P} \frac{4}{3}$ Naumann; 3 4 0 Miller; H^7 Brooke and Levy.

Fayalite	55° 20′	Manganite	57° 40′

The form $\frac{3}{2}\,1\,\infty$; $\infty \bar{P} \frac{3}{2}$ Naumann; 2 3 0 Miller; H^5 Brooke and Levy.

Baryte	61° 30′	Bournonite	57° 59′

The form $\frac{5}{3}\,1\,\infty$; $\infty \bar{P} \frac{5}{3}$ Naumann; 3 5 0 Miller; H^4 Brooke and Levy.

Cerussite	69° 36′

The form $2\,1\,\infty$; $\infty \bar{P}\,2$ Naumann; 1 2 0 Miller; H^3 Brooke and Levy.

Andalusite	63° 44′	Fayalite	65° 12′	Monticellite	66° 27′
Antimonite	63° 44′	Göthite	65° 20′	Niobite	67° 29′
Baryte	67° 50′	Ilvaite	71° 6′	Olivine	65° 1′
Bournonite	64° 52′	Libethenite	64° 22′	Struvite	42° 32′
Brookite	67° 11′	Manganite	67° 7′	Wolfram	67° 52′
Diaspore	64° 57′				

Diaspore has an imperfect cleavage parallel to the above form.

The form $4\,1\,\infty$; $\infty \bar{P}\,4$ Naumann; 1 4 0 Miller; $H^{\frac{5}{3}}$ Brooke and Levy.

Brookite	78° 7′	Manganite	78° 5′

The form $\frac{11}{2}\,1\,\infty$; $\infty \bar{P} \frac{11}{2}$ Naumann; 2 11 0 Miller; $H^{\frac{13}{9}}$ Brooke and Levy.

Brookite	81° 18′

The form $\frac{23}{4}\,1\,\infty$; $\infty \bar{P} \frac{23}{4}$ Naumann; 4 23 0 Miller; $H^{\frac{27}{19}}$ Brooke and Levy.

Brookite	81° 40′

Poles of these derived Rhombic Prisms of the First Order on the Sphere of Projection, &c.—If $G_1 l_1$, $G_1 l_2$, $G_2 l_3$, and $G_2 l_4$, on the equator of the sphere of projection, be each taken equal to the angle of longitude given above, in Fig. 307, l_1, l_2, l_3, and l_4, will be the four poles of the prism. If α be the angular element given in the first column, θ the longitude of the prism $n\,1\,\infty$, for any particular substance, then

$$\tan \theta = n \cot \alpha.$$

2θ will be the inclination of the faces of the prism over the edges $E_1 E_3$ or $E_2 E_4$ (Fig. 304); $180° - 2\theta$, their inclination over the edges $A_1 A_3$ and $A_2 A_4$.

Right Rhombic Prisms derived from the Right Rhombic Prism of the First Order, by increasing the Lesser Axis H_1 H_2.—These prisms are derived from the prism of the first order, by making CH_1 and CH_2 (Fig. 301) equal to n times CH (Fig. 301). With this alteration A_1, A_2, A_3, A_4, E_1, E_2, E_3 and E_4, will give the angular points of the new prism.

The symbol of these derived prisms will be $1\, n\, \infty$; $\infty \breve{P} n$ Naumann; $k\, h\, o$ Miller; $G^{\frac{n+1}{n-1}}$ Brooke and Levy.

Faces parallel to the following forms of these Prisms have been observed in nature; the angle is that of their longitude.

The form $1\, \frac{4}{3}\, \infty$; $\infty \breve{P} \frac{4}{3}$ Naumann; 4 3 0 Miller; G^{7} Brooke and Levy.

Anglesite	43° 34′	Antimonite	37° 14′	Bournonite	38° 39′
		Wavellite	56° 3′		

The form $1\, \frac{3}{2}\, \infty$; $\infty \breve{P} \frac{3}{2}$ Naumann; 3 2 0 Miller; G^{5} Brooke and Levy.

Diaspore	35° 30′	Manganite	38° 18′	Redruthite	48° 52′
Euchroite	47° 36′	Olivine	35° 35′	Topaz	51° 37′
Fayalite	35° 52′				

The form $1\, \frac{5}{2}\, \infty$; $\infty \breve{P} \frac{5}{2}$ Naumann; 5 2 0 Miller; $G^{\frac{7}{3}}$ Brooke and Levy.

Fayalite	23° 27′	Manganite	25° 21′

The form $1\, 2\, \infty$; $\infty \breve{P} 2$ Naumann; 2 1 0 Miller; G^{3} Brooke and Levy.

Aeschynite	45° 17′	Diaspore	28° 9′	Remolinite	36° 43′
Anglesite	32° 27′	Epsomite	26° 49′	Schulzite	30° 8′
Antimonsilber	40° 54′	Euchroite	39° 24′	Scorodite	29° 55′
Baryte	31° 33′	Goslarite	26° 43′	Sulphur	31° 49′
Bournonite	28° 4′	Göthite	28° 34′	Sylvanite	35° 56′
Brochantite	32° 42′	Ilvaite	36° 8′	Thermonatrite	53° 55′
Celestine	32° 38′	Manganite	30° 38′	Topaz	43° 26′
Chrysoberyl	56° 47′	Olivine	28° 13′	Wolfram	31° 35′
Cotunnite	30° 41′	Orpiment	39° 40′	Wolfsbergite	50° 30′
Datholite	32° 17′	Polymignite	35° 25′		

The form $1\, \frac{9}{4}\, \infty$; $\infty \breve{P} \frac{9}{4}$ Naumann; 9 4 0 Miller; $G^{\frac{13}{5}}$ Brooke and Levy.

Tantalite	28° 33′

The form $1\, 3\, \infty$; $\infty \breve{P} 3$ Naumann; 3 1 0 Miller; G^{2} Brooke and Levy.

Antimonsilber	30° 0′	Glaserite	30° 12′	Mengite	39° 46′
Bismuthine	18° 44′	Ilvaite	25° 57′	Niobite	21° 54′
Cerussite	28° 39′	Leadhillite	30° 10′	Smithsonite	25° 4′
Chrysoberyl	35° 21′	Manganite	21° 33′	Sylvanite	25° 47′
Cordierite	29° 35′	Mascagnine	30° 34′	Topaz	32° 16′
Datholite	22° 50′				

The form $1\frac{7}{2}\, \infty$; $\infty \breve{P} \frac{7}{2}$ Naumann; 7 2 0 Miller; $G^{\frac{9}{5}}$ Brooke and Levy.

Chrysoberyl	31° 17′

The form $1\, 4\, \infty$; $\infty \breve{P} 4$ Naumann; 4 1 0 Miller; $G^{\frac{5}{3}}$ Brooke and Levy.

Ilvaite	20° 3′	Polymignite	19° 35′	Topaz	25° 20′
Leadhillite	23° 33′	Remolinite	20° 28′		

The form $1\, 5\, \infty$; $\infty \breve{P} 5$ Naumann; 5 1 0 Miller; $G^{\frac{3}{2}}$ Brooke and Levy.

Antimonsilber	16° 6′	Antimonite	11° 27′	Smithsonite	14° 20′

Poles of these derived Rhombic Prisms of the First Order on the Sphere of Projection, &c.—Take $G_1 K_1$, $G_1 K_2$, $G_2 K_3$ and $G_2 K_4$ (Fig. 307) on the equator of the sphere of projection, each equal to the angle of longitude given above. $K_1 K_2 K_3$ and K_4 will be the four poles of the prism.

If α be the angular element given in the first column, θ the longitude of the prism, $1\, n\, \infty$ for any particular substance, then

$$\cot \theta = n \tan \alpha$$

2θ will be the inclination of the faces of the prism over the edges $A_1 A_3$, $A_2 A_4$ (Fig. 304); $180° - 2\theta$, their inclination over the edges $E_1 E_3$ or $E_2 E_4$.

Right Rhombic Prism of the Second Order.—The right rhombic prism of the second order is similar in form, but different in position, to that of the first order. The four faces (Fig. 308) which are rectangular parallelograms, cut the two axes P_1 P_2 and G_1 G_2 (Fig. 301) in the points P and G, and are parallel to the third axis H_1 H_2 (Fig. 301).

The rhombic planes A_1 M_1 A_3 M_4 and A_2 M_2 A_4 M_3 which inclose the prism are the macro-pinacoids.

To draw this prism, we have only to prick off the points A_1, A_2, A_3, A_4, E_1, E_2, E_2, and E_4 from the Fig. 301, and join them as in Fig. 308.

Symbols.—The symbol which represents the relation of this prism to the axes of the prismatic system is 1 ∞ 1; Naumann's $\breve{P}\infty$; Miller's 1 0 1; Brooke and Levy's $E^{\frac{1}{2}}$.

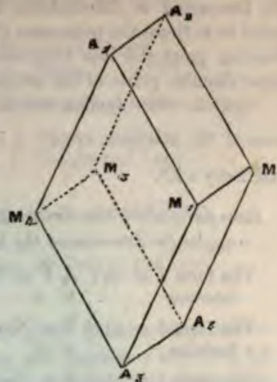


Fig. 308.

Faces parallel to the Prism of the Second Order occur in the following Minerals: the angle is that of their latitude.

Alstonite	36° 27′	Epsomite	29° 58′	Olivenite	34° 35′
Andalusite	35° 5′	Euchroite	46° 4′	Olivine	49° 33′
Anglesite	52° 15′	Fayalite	49° 11′	Phillipsite	34° 59′
Antimonsilber	33° 53′	Glaserite	36° 44′	Polianite	31° 0′
Antimonite	45° 36′	Goslarite	29° 58′	Pyrolusite	20° 0′
Aragonite	35° 47′	Göthite	31° 15′	Remolinite	37° 0′
Baryte	52° 42′	Haidingerite	26° 31′	Smithsonite	25° 47′
Bournonite	41° 54′	Harmotome	34° 47′	Stephanite	34° 26′
Brochantite	14° 4′	Karstenite	44° 25′	Strontianite	35° 54′
Caledonite	54° 31′	Leadhillite	51° 38′	Struvite	31° 34′
Celestine	52° 4′	Libethenite	35° 4′	Sulphur	62° 12′
Cerussite	35° 52′	Lölingite	48° 50′	Sylvanite	31° 26′
Chrysoberyl	30° 7′	Manganite	28° 35′	Tantalite	33° 6′
Cordierite	29° 11′	Marcasite	49° 0′	Thermonatrite	48° 5′
Cotunnite	26° 38′	Mascagnine	36° 10′	Topaz	43° 31′
Datholite	26° 34′	Mispickel	49° 56′	Valentinite	54° 44′
Diaspore	30° 29′	Monticellite	48° 46′	Withurite	36° 33′
Epistilbite	16° 10′	Nitre	35° 1′	Wolfram	40° 46′

The following present Cleavages parallel to this form.

Andalusite	Aragonite	Epsomite	Lolingite	*Nitre*
Antimonsilber	Bournonite	Euchroite	Marcasite	Topaz

Position of the poles of the Right Rhombic Prism of the Second Order on the Sphere of Projection.

The four poles of this prism all lie in the same meridian or zone G_1 P_1 G_2, (Fig. 307). The poles a_1, a_2 in the northern hemisphere for any particular substance are determined by observing where the circle of latitude, whose north polar distance is equal to the angle of latitude given above, cuts the meridian G_1 P_1 G_2, the other two poles are where the same circle of south latitude cuts the same meridian.

The angle for determining the latitude of the poles of this form is that given in the second column of the angular elements, for substances belonging to the prismatic system. Let β represent this angle.

Then 2β and $180° - 2\beta$ are the inclinations of the faces of this prism to each other.

Right Rhombic Prisms derived from those of the Second Order.—By increasing or diminishing the axis $P_1 P_2$ (Fig. 301), by making CP_1 (Fig. 301) equal to m times the parameter CP (Fig. 302), where m may be any whole number or fraction greater or less than unity, and then from Fig. 301 so altered constructing a right rhombic prism of the second order, a new series of prisms may be described.

Symbols.—The symbol which will represent the relation of these prisms to the axes of the prismatic system is $1 \infty m$; Naumann's is $m \breve{P} \infty$; Miller's $h\ o\ l$; Brooke and Levy's $E^{\frac{m}{2}}$.

Faces parallel to these derived Rhombic Prisms of the Second Order, with the following angles for determining the latitude of their poles, have been observed in nature.

The form $1 \infty \frac{1}{12}$; $\frac{1}{12} \breve{P} \infty$ Naumann; 1, 0, 12 Miller; $E^{\frac{1}{24}}$ Brooke and Levy.

Celestine	6° 6′				

The form $1 \infty \frac{1}{6}$; $\frac{1}{6} \breve{P} \infty$ Naumann; 1 0 6 Miller; $E^{\frac{1}{12}}$ Brooke and Levy.

Tantalite	6° 11′				

The form $1 \infty \frac{1}{4}$; $\frac{1}{4} \breve{P} \infty$ Naumann; 1 0 4 Miller; $E^{\frac{1}{8}}$ Brooke and Levy.

Gadolinite	16° 52′	Marcasite	16° 30′	Mispickel	16° 16′

The form $1 \infty \frac{1}{3}$; $\frac{1}{3} \breve{P} \infty$ Naumann; 1 0 3 Miller; $E^{\frac{1}{6}}$ Brooke and Levy.

Celestine	23° 9′	Marcasite	21° 33′	Sulphur	32° 18′
		Valentinite	25° 14′		

The form $1 \infty \frac{1}{2}$; $\frac{1}{2} \breve{P} \infty$ Naumann; 1 0 2 Miller; $E^{\frac{1}{4}}$ Brooke and Levy.

Antimonite	27° 4′	Ilvaite	12° 51′	Olivine	30° 24′
Aragonite	19° 49′	Leadhillite	32° 16′	Smithsonite	13° 34′
Baryte	33° 17′	Mispickel	31° 4′	Stromeyerite	25° 58′
Cerussite	19° 52′	Marcasite	30° 38′	Thermonatrite	29° 7′
Fayalite	30° 4′	Nitre	19° 19′	Witherite	20° 21′
Glaserite	56° 11′				

The form $1 \infty \frac{2}{3}$; $\frac{2}{3} \breve{P} \infty$ Naumann; 2 0 3 Miller; $E^{\frac{1}{3}}$ Brooke and Levy.

Datholite	18° 26′	Roselite	22° 30′	Topaz	32° 19′
Redruthite	32° 54′	Sulphur	51° 40′	Wolfram	29° 54′

The form $1 \infty \frac{4}{3}$; $\frac{4}{3} \breve{P} \infty$ Naumann; 4 0 3 Miller; $E^{\frac{2}{3}}$ Brooke and Levy.

Brookite	51° 32′	Datholite	33° 41′		

The form $1 \infty \frac{3}{2}$; $\frac{3}{2} \breve{P} \infty$ Naumann; 3 0 2 Miller; $E^{\frac{3}{4}}$ Brooke and Levy.

Aragonite	47° 14′	Herderite	32° 30′	Staurolite	45° 48′
		Strontianite	47° 22′		

The form $1 \infty 2$; $2 \breve{P} \infty$ Naumann; 2 0 1 Miller; E^{1} Brooke and Levy.

Aeschynite	53° 13′	Epsomite	49° 4′	Redruthite	62° 44′
Alstonite	55° 55′	Harmotome	54° 15′	Smithsonite	44° 0′
Antimonsilber	53° 20′	Ilvaite	42° 23′	Stephanite	53° 34′
Aragonite	55° 15′	Leadhillite	68° 24′	Sternbergite	59° 12′
Brookite	62° 6′	Mascagnine	55° 37′	Strontianite	55° 22′
Cerussite	55° 20′	Niobite	60° 20′	Sylvanite	50° 43′
Childrenite	52° 7′	Nitre	54° 30′	Topaz	62° 13′
Datholite	45° 0′	Olivine	66° 55′	Witherite	56° 0′

Cerussite, Stephanite, Strontianite, and Witherite cleave parallel to this form.

The form $1 \infty 3$; $3 \breve{P} \infty$ Naumann; 3 0 1 Miller; $E^{\frac{3}{2}}$ Brooke and Levy.

Aragonite	65° 11′	Mispickel	74° 32′	Sylvanite	61° 23′
Cerussite	65° 15′	Smithsonite	55° 23′	Tantalite	62° 58′
Datholite	56° 19′				

The form $1 \infty 4$; $4 \breve{P} \infty$ Naumann; 4 0 1 Miller; E^{2} Brooke and Levy.

Cerussite	70° 55′	Strontianite	70° 57′	Topaz	75° 15′
Datholite	63° 26′	Sylvanite	67° 45′	Valentinite	79° 58′
Prehnite	73° 30′				

The form $1 \infty 5$; $5 \breve{\bar{P}} \infty$ Naumann; 5 0 1 Miller; $E^{\frac{5}{2}}$ Brooke and Levy.
Aragonite . . 74° 29′ | Smithsonite . . 67° 30′

The form $1 \infty 6$; $6 \breve{\bar{P}} \infty$ Nauman 6 0 1 Miller; E^3 Brooke and Levy.
Aragonite . . 76° 59′ | Herderite . . 68° 34′ | Strontianite . . 77° 2′

The form $1 \infty 7$; $7 \breve{\bar{P}} \infty$ Naumann; 7 0 1 Miller; $E^{\frac{7}{2}}$ Brooke and Levy.
Smithsonite . . 73° 31′

The form $1 \infty 8$; $8 \breve{\bar{P}} \infty$ Naumann; 8 0 1 Miller; E^4 Brooke and Levy.
Strontianite . . 80° 12′

The form $1 \infty 10$; $10 \breve{\bar{P}} \infty$ Naumann; 10, 0, 1 Miller; E^5 Brooke and Levy.
Sternbergite . . 83° 12′

The form $1 \infty 12$; $12 \breve{\bar{P}} \infty$ Naumann; 12, 0, 1 Miller; E^6 Brooke and Levy.
Strontianite . . 83° 26′

Poles of the derived Rhombic Prisms of the Second Order on the Sphere of Projection.—Let λ be the angle given in the list above for determining the latitude of any form for a particular substance. The two points where the circle of north latitude, whose polar distance from P_1 is λ, cuts the meridian or zone G_1 P_1 G_2 (Fig. 307); and the two points where the same circle of south latitude cuts the same zone, will give the four poles of the derived rhombic prism.

Let β be the angle given in the second column (pages 417, 418),

$$\tan \lambda = m \tan \beta.$$

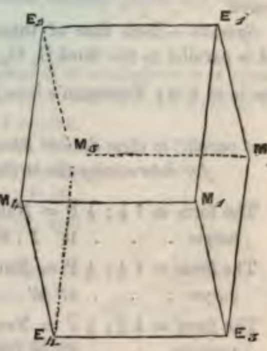


Fig. 309.

Right Rhombic Prism of the Third Order.—The right rhombic prism of the third order is similar in form to that of the first order, but differs in position with regard to the axes.

Symbols.—Each face passes through one of the extremities of the axes $P_1 P_2$ and $H_1 H_2$, and is parallel to the third axis $G_1 G_2$. The *symbol* which expresses this relation is $\infty 1 1$; Naumann's is $\bar{P} \infty$; Miller's 0 1 1; Brooke and Levy's $A^{\frac{1}{2}}$.

To draw this prism prick off the points E_1, E_2, E_3, E_4 and M_1, M_2, M_3, M_4 from Fig. 301, and join them as in Fig. 309.

Faces parallel to the Prism of the Third Order occur in the following minerals: the angle is that of their latitude.

Andalusite . .	35° 26′	Goslarite . . .	29° 50′	Remolinite . .	48° 31′
Antimonsilber .	49° 19′	Göthite . . .	33° 30′	Smithsonite . .	31° 40′
Aragonite . .	49° 10′	Ilvaite . . .	33° 40′	Staurolite . .	55° 22′
Baryte . . .	58° 10′	Liroconite . .	53° 49′	Stilbite . . .	39° 8′
Bournonite . .	43° 43′	Lolingite . .	64° 20′	Struvite . .	48° 25′
Chrysoberyl . .	50° 59′	Manganite . .	32° 50′	Sulphur . . .	66° 53′
Datholite . .	32° 17′	Mispickel . . .	60° 24′	Sylvanite . .	41° 32′
Epistilbite . .	35° 7′	Olivenite . .	35° 46′	Topaz . . .	60° 55′
Epsomite . .	29° 58′	Olivine . . .	51° 33′	Wavellite . .	36° 37′
Eudnophite, undetermined.		Orpiment . .	48° 30′	Wölchite, undetermined.	
Fayalite . .	51° 28′	Prehnite . . .	45° 7′	Zinckenite . .	14° 42′

The following present Cleavages parallel to this form.

Bournonite. Liroconite. Remolinite. *Smithsonite.* Topaz.

Position of the Poles of the Right Rhombic Prism of the Third Order on the Sphere of Projection.—Let λ be the angle given in the above list for determining the latitude for any particular substance. The two points b_1, b_2 (Fig. 307) where the circle of north latitude, whose polar distance from P_1 is λ, cuts the meridian $G_1\ PG_2$, and the two points where the same circle of south latitude cuts the same meridian, will give the four poles of the rhombic prism of the third order.

Let α be the angle given in the first column, and β that given in the second column (pages 417, 418). Then λ may be obtained from the formula

$$\tan \lambda = \frac{\tan \beta}{\tan \alpha}$$

Right Rhombic Prisms derived from those of the Third Order.—By taking CP_1 (Fig. 301) m times CP (Fig. 302) where m may be any fraction or whole number; and from Fig. 301 so altered, describing a right rhombic prism of the third order, a series of prisms similar in form and position, but differing in magnitude from Fig. 309, may be formed.

Symbols.—Each face of these derived prisms cuts two of the axes $P_1\ P_2$, $H_1\ H_2$, and is parallel to the third $G_1\ G_2$, and the symbol which expresses this relation to the axes is $\infty\ 1\ m$; Naumann's is $m\ \overline{P}\ \infty$; Miller's $o\ k\ l$; and Brooke and Levy's $A^{\frac{m}{2}}$

Faces parallel to these derived Rhombic Prisms of the Third Order, with the following angles for determining the latitude of their poles, have been observed in nature.

The form $\infty\ 1\ \frac{1}{6}$; $\frac{1}{6}\ \overline{P}\ \infty$ Naumann; 0 1 6 Miller; $A^{\frac{1}{12}}$ Brooke and Levy.

Baryte . . .	15° 2′	Niobite . . .	10° 0′

The form $\infty\ 1\ \frac{1}{5}$; $\frac{1}{5}\ \overline{P}\ \infty$ Naumann; 0 1 5 Miller; $A^{\frac{1}{10}}$ Brooke and Levy.

Baryte . . .	17° 52′

The form $\infty\ 1\ \frac{1}{4}$; $\frac{1}{4}\ \overline{P}\ \infty$ Naumann; 0 1 4 Miller; $A^{\frac{1}{8}}$ Brooke and Levy.

Anglesite . .	22° 20′	Bournonite . .	13° 27′	Celestine . .	22° 22′
Baryte . . .	21° 56′	Brookite . .	15° 40′	Leadhillite . .	28° 50′

The form $\infty\ 1\ \frac{1}{3}$; $\frac{1}{3}\ \overline{P}\ \infty$ Naumann; 0 1 3 Miller; $A^{\frac{1}{6}}$ Brooke and Levy.

Baryte . . .	28° 14′	Cerussite . .	21° 33′	Sulphur . . .	37° 58′
Celestine . .	28° 43′	Niobite . . .	19° 26′	Topaz . . .	30° 55′

The form $\infty\ 1\ \frac{1}{2}$; $\frac{1}{2}\ \overline{P}\ \infty$ Naumann; 0 1 2 Miller; $A^{\frac{1}{4}}$ Brooke and Levy.

Anglesite . .	39° 27′	Cerussite . .	30° 39′	Prehnite . .	26° 40′
Baryte . . .	38° 51′	Epsomite . .	48° 47′	Strontianite . .	30° 43′
Bournonite . .	25° 33′	Glaserite . .	33° 5′	Sylvanite . .	23° 53′
Brookite . .	29° 18′	Haidingerite . .	16° 33′	Wolfram . .	28° 1′
Celestine . .	39° 24′	Leadhillite . .	47° 45′		

Baryte has an imperfect cleavage parallel to this form.

The form $\infty\ 1\ \frac{2}{3}$; $\frac{2}{3}\ \overline{P}\ \infty$ Naumann; 0 2 3 Miller; $A^{\frac{1}{3}}$ Brooke and Levy.

Bournonite . .	32° 31′	Chrysoberyl . .	39° 27′	Niobite . . .	35° 12′

The form $\infty\ 1\ \frac{3}{4}$; $\frac{3}{4}\ \overline{P}\ \infty$ Naumann; 0 3 4 Miller; $A^{\frac{3}{8}}$ Brooke and Levy.

Celestine . .	50° 57′	Leadhillite . .	74° 24′

The form $\infty\ 1\ \frac{3}{2}$; $\frac{3}{2}\ \bar{P}\ \infty$ Naumann; 0 3 2 Miller; $A^{\frac{3}{4}}$ Brooke and Levy.

Datholite	43° 27′	Sylvanite	53° 2′

The form ∞ 1 2; $2\ \bar{P}\ \infty$ Naumann; 0 2 1 Miller; A^1 Brooke and Levy.

Bournonite	62° 24′	Datholite	51° 38′	Polykrase	62° 0′
Brochantite	32° 54′	Haidingerite	49° 56′	Scorodite	65° 30′
Caledonite	71° 55′	Manganite	52° 14′	Smithsonite	50° 58′

The form ∞ 1 3; $3\ \bar{P}\ \infty$ Naumann; 0 3 1 Miller; $A^{\frac{3}{2}}$ Brooke and Levy.

Ilvaite	63° 25′	Smithsonite	61° 37′

The form ∞ 1 4; $4\ \bar{P}\ \infty$ Naumann; 0 4 1 Miller; A^2 Brooke and Levy.

Haidingerite . . 67° 11′

The form ∞ 1 6; $6\ \bar{P}\ \infty$ Naumann; 0 6 1 Miller; A^3 Brooke and Levy.

Sternbergite . . 76° 31′

Position of the Poles of the derived Rhombic Prisms of the Third Order on the Sphere of Projection.—Let b_1 and b_2 (Fig. 307) be the points where the circle of latitude, whose polar distance from P_1 is the angle λ given for each particular substance in the preceding article, cuts the meridian $H_1\ PH_2$; these points, together with two similar ones where the same circle of south latitude cuts $H_1\ PH_2$, will be the four poles of the rhombic prism.

If α be the angle in the first, and β that in the second column (pages 417, 418),

$$\tan \lambda = m \frac{\tan \beta}{\tan \alpha}$$

Rhombic Pyramid.—The *double four-faced pyramid* or *octahedron on a rhombic base* is a solid bounded by eight triangular faces; each face, such as $P_1\ H_1\ G_1$ (Fig. 310) being a scalene triangle. It has six four-faced solid angles, equal to one another in pairs, that at P_1 being equal to that at P_2, at H_1 to H_2, and at G_1 to G_2. The edge $P_1\ H_1$ equals $H_1\ P_2$, $H_2\ P_2$, and $P_1\ H_2$; the edge $P_1\ G_1$ equals $P_1\ G_2$, $P_2\ G_1$, and $P_2\ G_2$; and the edge $H_1\ G_1$ equals $G_1\ H_2$, $H_2\ G_2$, and $G_2\ H_1$.

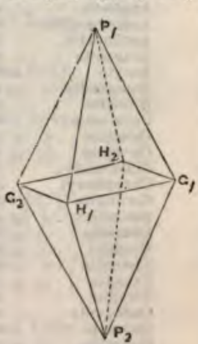


Fig. 310.

To draw the Rhombic Pyramid.—Prick off from Fig. 301 the points P_1, P_2, H_1, H_2, G_1 and G_2, and join these as in Fig. 310.

Axes.—The prismatic axes join the opposite four-faced solid angles of the rhombic pyramid.

Symbols.—Every face of the pyramid cuts the three axes $P_1\ P_2$, $G_1\ G_2$, and $H_1\ H_2$ at the extremities of the parameters; the symbol which expresses this relation is 1 1 1; Naumann's is P; Miller's 1 1 1; and Brooke and Levy's B.

Position of the Poles of the Rhombic Pyramid on the Sphere of Projection.—Four of the poles of this pyramid lie in the same parallel of north latitude, and four in the same parallel of south latitude.

Let λ be the polar distance of the pole e_1 (Fig. 307) of the face $P_1\ H_2\ G_1$ (Fig. 310) from P_1; μ its longitude from G_1 or the arc GD_1.

Then the eight poles of the rhombic pyramid will be where the north and south circles of latitude, whose polar distances are equal to λ, cut the meridians of longitude μ, $180 - \mu$, $180 + \mu$, and $360 - \mu$.

If α and β be the angles given in the first and second columns (pages 417 and 418),

$$\text{Then } \mu = 90 - \alpha, \text{ and } \tan \lambda = \tan \beta \operatorname{cosec} \alpha.$$

To describe a Net for the Rhombic Pyramid.

Draw two lines, CG and CP (Fig. 311); at right angles to each other; take C

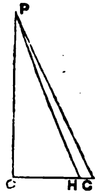


Fig. 311.

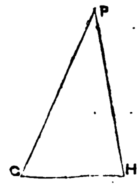


Fig. 312.

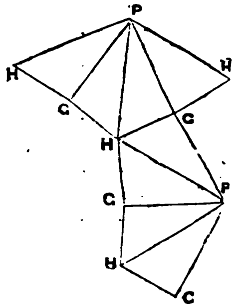


Fig. 313.

equal CP (Fig. 302), and CG and CH equal to CG and CH (Fig. 302). Join PH and PG.

Then (Fig. 312) take GH equal to GH (Fig. 302), and on GH, as a base, describe the triangle PGH, having its sides PG and PH equal to PG and PH (Fig. 311). Eight of these triangles, arranged as in Fig. 313, will give the required net.

Faces parallel to the Rhombic Prism whose symbol is 1 1 1, *with the following Angles for determining the position of their Poles, have been observed in nature.*

Aeschynite	$\lambda = 48^\circ\ 28'$	$\mu = 63^\circ\ 40'$	Marcasite	$\lambda = 63^\circ\ 5'$	$\mu = 53^\circ\ 3'$
Alstonite	$\lambda = 55^\circ\ 27'$	$\mu = 59^\circ\ 26'$	Mascagnine	$\lambda = 56^\circ\ 5'$	$\mu = 60^\circ\ 34'$
Anglesite	$\lambda = 64^\circ\ 27'$	$\mu = 51^\circ\ 49'$	Mengite	$\lambda = 48^\circ\ 10'$	$\mu = 39^\circ\ 46'$
Antimonsilber	$\lambda = 53^\circ\ 20'$	$\mu = 60^\circ\ 0'$	Mesotype	$\lambda = 26^\circ\ 40'$	$\mu = 45^\circ\ 30'$
Antimonite	$\lambda = 55^\circ\ 29'$	$\mu = 45^\circ\ 28'$	Mispickel	$\lambda = 64^\circ\ 53'$	$\mu = 55^\circ\ 36'$
Aragonite	$\lambda = 53^\circ\ 44'$	$\mu = 58^\circ\ 5'$	Niobite	$\lambda = 53^\circ\ 58'$	$\mu = 50^\circ\ 20'$
Baryte	$\lambda = 64^\circ\ 18'$	$\mu = 50^\circ\ 50'$	Nitre	$\lambda = 54^\circ\ 1'$	$\mu = 59^\circ\ 25'$
Bournonite	$\lambda = 52^\circ\ 40'$	$\mu = 46^\circ\ 50'$	Olivine	$\lambda = 59^\circ\ 51'$	$\mu = 47^\circ\ 1'$
Brookite	$\lambda = 55^\circ\ 43'$	$\mu = 49^\circ\ 55'$	Orpiment	$\lambda = 52^\circ\ 35'$	$\mu = 58^\circ\ 55'$
Caledonite	$\lambda = 64^\circ\ 17'$	$\mu = 47^\circ\ 30'$	Phillipsite	$\lambda = 45^\circ\ 0'$	$\mu = 45^\circ\ 36'$
Celestine	$\lambda = 64^\circ\ 22'$	$\mu = 52^\circ\ 1'$	Polykrase	$\lambda = 45^\circ\ 1'$	$\mu = 70^\circ\ 0'$
Cerussite	$\lambda = 54^\circ\ 14'$	$\mu = 58^\circ\ 37'$	Polymignite	$\lambda = 40^\circ\ 8'$	$\mu = 54^\circ\ 53'$
Childrenite	$\lambda = 48^\circ\ 56'$	$\mu = 55^\circ\ 57'$	Redruthite	$\lambda = 62^\circ\ 36'$	$\mu = 59^\circ\ 48'$
Chrysoberyl	$\lambda = 53^\circ\ 14'$	$\mu = 64^\circ\ 49'$	Remolinite	$\lambda = 53^\circ\ 42'$	$\mu = 56^\circ\ 10'$
Cordierite	$\lambda = 47^\circ\ 48'$	$\mu = 59^\circ\ 35'$	Roselite	$\lambda = 57^\circ\ 12'$	$\mu = 66^\circ\ 24'$
Cotunnite	$\lambda = 37^\circ\ 54'$	$\mu = 49^\circ\ 53'$	Schulzite	Unknown.	
Datholite	$\lambda = 38^\circ\ 51'$	$\mu = 51^\circ\ 38'$	Scorodite	$\lambda = 55^\circ\ 29'$	$\mu = 29^\circ\ 53'$
Diaspore	$\lambda = 40^\circ\ 57'$	$\mu = 46^\circ\ 56'$	Stephanite	$\lambda = 52^\circ\ 10'$	$\mu = 37^\circ\ 50'$
Epsomite	$\lambda = 39^\circ\ 3'$	$\mu = 45^\circ\ 17'$	Sternbergite	$\lambda = 59^\circ\ 0'$	$\mu = 59^\circ\ 45'$
Fayalite	$\lambda = 59^\circ\ 39'$	$\mu = 47^\circ\ 20'$	Stilbite	$\lambda = 48^\circ\ 0'$	$\mu = 47^\circ\ 8'$
Fluellite	$\lambda = 72^\circ\ 0'$	$\mu = 48^\circ\ 54'$	Strontianite	$\lambda = 54^\circ\ 17'$	$\mu = 58^\circ\ 40'$
Gadolonite	$\lambda = 67^\circ\ 27'$	$\mu = 59^\circ\ 45'$	Struvite	$\lambda = 52^\circ\ 6'$	$\mu = 61^\circ\ 25'$
Glaserite	$\lambda = 56^\circ\ 20'$	$\mu = 60^\circ\ 12'$	Sulphur	$\lambda = 71^\circ\ 39'$	$\mu = 50^\circ\ 59'$
Goslarite	$\lambda = 39^\circ\ 2'$	$\mu = 45^\circ\ 21'$	Sylvanite	$\lambda = 47^\circ\ 6'$	$\mu = 55^\circ\ 24'$
Göthite	$\lambda = 41^\circ\ 53'$	$\mu = 47^\circ\ 26'$	Tantalite	$\lambda = 45^\circ\ 51'$	$\mu = 50^\circ\ 46'$
Harmotome	$\lambda = 44^\circ\ 56'$	$\mu = 45^\circ\ 53'$	Thenardite	$\lambda = 61^\circ\ 51'$	$\mu = 64^\circ\ 41'$
Herderite	$\lambda = 38^\circ\ 41'$	$\mu = 57^\circ\ 57'$	Thermonatrite	$\lambda = 72^\circ\ 56'$	$\mu = 69^\circ\ 59'$
Ilvaite	$\lambda = 33^\circ\ 55'$	$\mu = 55^\circ\ 36'$	Topaz	$\lambda = 63^\circ\ 48'$	$\mu = 62^\circ\ 10'$
Karstenite	$\lambda = 55^\circ\ 50'$	$\mu = 48^\circ\ 18'$	Wavellite	$\lambda = 39^\circ\ 47'$	$\mu = 63^\circ\ 13'$
Leadhillite	$\lambda = 68^\circ\ 30'$	$\mu = 60^\circ\ 10'$	Witherite	$\lambda = 55^\circ\ 24'$	$\mu = 59^\circ\ 15'$
Libethenite	$\lambda = 45^\circ\ 23'$	$\mu = 46^\circ\ 10'$	Wolfram	$\lambda = 53^\circ\ 55'$	$\mu = 50^\circ\ 53'$
Manganite	$\lambda = 40^\circ\ 11'$	$\mu = 49^\circ\ 50'$			

Inclination of the Faces of the Rhombic Pyramid.—If θ be the angle of inclination of two faces over any of the edges HG (Fig. 310), ϕ over the edges PH, and ψ over the edges PG,

$$\theta = 2\lambda \qquad \cos\frac{\phi}{2} = \tan\beta\cos\lambda \qquad \sin\frac{\psi}{2} = \frac{\tan\beta\cos\lambda}{\tan\alpha}$$

Derived Rhombic Pyramids.—From the rhombic pyramid just described, a series of rhombic pyramids may be derived, similar in position, but differing in magnitude from the fundamental pyramid from which they are derived. These pyramids may conveniently be divided into three classes.

Derived Rhombic Pyramid of the First Class.—This pyramid is derived from the fundamental pyramid, by making the vertical axes CP_1 and CP_2 (Fig. 301) equal to m times the parameter CP (Fig. 302), where m may be any whole number, or fraction greater or less than unity.

Symbols.—The symbol for this pyramid is $1\ 1\ m$; Naumann's $m\text{P}$; Miller's $h\ h\ l$; and Brooke and Levy's $\text{B}^{\frac{1}{m}}$.

Inclination of Faces, Position of Poles, &c.—If the symbols α, β, λ, μ, θ, ϕ, and ψ represent the same angles as in the case of the fundamental pyramid,

$$\mu = (90^\circ - \alpha) \quad \tan\lambda = m \tan\beta \operatorname{cosec}\alpha$$

$$\theta = 2\lambda \quad \cos\frac{\phi}{2} = m\tan\beta\cos\lambda \quad \sin\frac{\psi}{2} = m\,\frac{\tan\beta\cos\lambda}{\tan\alpha}$$

The poles of this pyramid always lie in the two zones $D_1\ P_1\ D_3$ and $D_2P_1\ D_4$ (Fig. 307), being between the points P and C when m is less than unity, and between C and D when m is greater than unity.

Faces parallel to the following Pyramids of the First Class have been observed in nature.

The form $1\ 1\ \frac{1}{8}$; $\frac{1}{8}$ P Naumann; 1 1 8 Miller; B^8 Brooke and Levy.

Baryte	$\lambda = 14^\circ 34'$	$\mu = 50^\circ 50'$			

The form $1\ 1\ \frac{1}{6}$; $\frac{1}{6}$ P Naumann; 1 1 6 Miller; B^6 Brooke and Levy.

Anglesite	$\lambda = 19^\circ 22'$	$\mu = 51^\circ 49'$			

The form $1\ 1\ \frac{1}{5}$; $\frac{1}{5}$ P Naumann; 1 1 5 Miller; B^5 Brooke and Levy.

Baryte	$\lambda = 22^\circ 34'$	$\mu = 50^\circ 50'$	Sulphur	$\lambda = 31^\circ\ 5'$	$\mu = 50^\circ 59'$

The form $1\ 1\ \frac{1}{4}$; $\frac{1}{4}$ P Naumann; 1 1 4 Miller; B^4 Brooke and Levy.

Baryte	$\lambda = 27^\circ 27'$	$\mu = 50^\circ 50'$	Sylvanite	$\lambda = 15^\circ\ 4'$	$\mu = 55^\circ 24'$
Celestine	$\lambda = 27^\circ 31'$	$\mu = 52\ \ 1'$	Topaz	$\lambda = 26^\circ 56'$	$\mu = 62^\circ 10'$
Stromeyerite	$\lambda = 25^\circ 44'$	$\mu = 59^\circ 48'$			

The form $1\ 1\ \frac{1}{3}$; $\frac{1}{3}$ P Naumann; 1 1 3 Miller; B^3 Brooke and Levy.

Antimonite	$\lambda = 25^\circ 53'$	$\mu = 45^\circ 23'$	Sulphur	$\lambda = 45^\circ\ 8'$	$\mu = 50^\circ 59'$
Baryte	$\lambda = 34^\circ 43'$	$\mu = 50^\circ 50'$	Sylvanite	$\lambda = 19^\circ 44'$	$\mu = 55^\circ 24'$
Celestine	$\lambda = 34^\circ 47'$	$\mu = 52^\circ\ 1'$	Thenardite	$\lambda = 31^\circ 56'$	$\mu = 64^\circ 41'$
Cerussite	$\lambda = 24^\circ 50'$	$\mu = 58^\circ 37'$	Topaz	$\lambda = 34^\circ\ 7'$	$\mu = 62^\circ 10'$
Karstenite	$\lambda = 26^\circ 10'$	$\mu = 48^\circ 18'$	Wolfram	$\lambda = 24^\circ 35'$	$\mu = 50^\circ 53'$
Redruthite	$\lambda = 32^\circ 44'$	$\mu = 59^\circ 48'$			

The form $1\ 1\ \frac{1}{2}$; $\frac{1}{2}$ P Naumann; 1 1 2 Miller; B^2 Brooke and Levy.

Anglesite	$\lambda = 46^\circ 16'$	$\mu = 51^\circ 49'$	Redruthite	$\lambda = 43^\circ 57'$	$\mu = 59^\circ 48'$
Antimonsilber	$\lambda = 33^\circ 53'$	$\mu = 60^\circ\ 0'$	Scorodite	$\lambda = 36^\circ\ 1'$	$\mu = 29^\circ 55'$
Baryte	$\lambda = 45^\circ\ 6'$	$\mu = 50^\circ 50'$	Stephanite	$\lambda = 32^\circ 46'$	$\mu = 57^\circ 50'$
Bournonite	$\lambda = 33^\circ 14'$	$\mu = 46^\circ 50'$	Strontianite	$\lambda = 34^\circ 49'$	$\mu = 58^\circ 40'$
Brookite	$\lambda = 36^\circ 15'$	$\mu = 49^\circ 55'$	Stromeyerite	$\lambda = 43^\circ 57'$	$\mu = 59^\circ 48'$
Cerussite	$\lambda = 34^\circ 46'$	$\mu = 58^\circ 37'$	Sulphur	$\lambda = 56^\circ 26'$	$\mu = 50^\circ 59'$
Cordierite	$\lambda = 28^\circ 53'$	$\mu = 59^\circ 35'$	Sylvanite	$\lambda = 28^\circ 17'$	$\mu = 55^\circ 24'$
Glaserite	$\lambda = 36^\circ 54'$	$\mu = 60^\circ 12'$	Topaz	$\lambda = 45^\circ 28'$	$\mu = 62^\circ 10'$
Karstenite	$\lambda = 36^\circ 23'$	$\mu = 48^\circ 18'$	Witherite	$\lambda = 35^\circ 56'$	$\mu = 59^\circ 15'$
Leadhillite	$\lambda = 51^\circ 46'$	$\mu = 60^\circ 10'$			

The form $1\ 1\ \frac{2}{3}$; $\frac{2}{3}$ P Naumann; 2 2 3 Miller; $\text{B}^{\frac{3}{2}}$ Brooke and Levy.

Caledonite	$\lambda = 54^\circ 10'$	$\mu = 47^\circ 30'$	Childrenite	$\lambda = 37^\circ 25'$	$\mu = 55^\circ 57'$

The form $1\ 1\ \frac{4}{5}$; $\frac{4}{5}$ P Naumann; 4 4 5 Miller; $\text{B}^{\frac{5}{4}}$ Brooke and Levy.

Strontianite	$\lambda = 48^\circ\ 3'$	$\mu = 58^\circ 40'$			

The form 1 1 $\frac{4}{3}$; $\frac{4}{3}$ P Naumann; 4 4 3 Miller; $B^{\frac{3}{4}}$ Brooke and Levy.

Prehnite . . $\lambda = 68° 15'$ $\mu = 49° 58'$

The form 1 1 $\frac{3}{2}$; $\frac{3}{2}$ P Naumann; 3 3 2 Miller; $B^{\frac{2}{3}}$ Brooke and Levy.

Strontianite . $\lambda = 64° 24'$ $\mu = 58° 40'$ | Sylvanite . . $\lambda = 58° 13'$ $\mu = 55° 24'$

The form 1 1 2; 2 P Naumann; 2 2 1 Miller; $B^{\frac{1}{2}}$ Brooke and Levy.

Alstonite . . $\lambda = 71° 0'$ $\mu = 59° 26'$
Brookite . . $\lambda = 71° 11'$ $\mu = 49° 55'$
Datholite . . $\lambda = 58° 10'$ $\mu = 51° 38'$
Manganite . $\lambda = 30° 37'$ $\mu = 49° 50'$
Stephanite . $\lambda = 68° 46'$ $\mu = 57° 50'$
Sternbergite . $\lambda = 73° 17'$ $\mu = 59° 45'$
Strontianite . $\lambda = 70° 14'$ $\mu = 58° 40'$

The form 1 1 3; 3 P Naumann; 3 3 1 Miller; $B^{\frac{1}{3}}$ Brooke and Levy.

Herderite . . $\lambda = 67° 25'$ $\mu = 57° 57'$ | Strontianite . $\lambda = 76° 31'$ $\mu = 58° 40'$

The form 1 1 4; 4 P Naumann; 4 4 1 Miller; $B^{\frac{1}{4}}$ Brooke and Levy.

Datholite . . $\lambda = 72° 45'$ $\mu = 51° 38'$
Herderite . . $\lambda = 72° 39'$ $\mu = 57° 57'$
Prehnite . . $\lambda = 79° 13'$ $\mu = 49° 58'$
Strontianite . $\lambda = 79° 49'$ $\mu = 58° 40'$

The form 1 1 8; 8 P Naumann; 8 8 1 Miller; $B^{\frac{1}{8}}$ Brooke and Levy.

Strontianite . $\lambda = 84° 52'$ $\mu = 58° 40'$

Derived Rhombic Pyramid of the Second Class.—This pyramid is derived from the fundamental pyramid by making the vertical axes CP_1 and CP_2 (Fig. 301) equal to *m* times the parameter CP (Fig. 302); where *m* may be any whole number or fraction, equal to, greater, or less than unity; and the lesser horizontal axes CH_1 and CH_2 (Fig. 301) equal to *n* times the parameter CH (Fig. 302), where *n* may be any whole number or fraction greater than unity.

Symbols.—The symbol for these pyramids is 1 *n m*; Naumann's $m\breve{P}n$; Miller's *h k l*; Brooke and Levy's $B^1 B^{\overline{\frac{n+1}{n-1}}} G^{\overline{\frac{m(n+1)}{2n}}}$.

Inclination of Faces, Position of Poles, &c.—If the symbols α, β, λ, μ, θ, φ, and ψ represent the same angles as in the case of the fundamental pyramid,

$$\cot \mu = n \tan \alpha \quad \tan \lambda = m \tan \beta \sec \mu \quad \theta = 2\lambda$$

$$\cos \frac{\phi}{2} = m \tan \beta \cos \lambda \quad \sin \frac{\psi}{2} = \frac{m}{n} \frac{\tan \beta \cos \lambda}{\tan \alpha}.$$

Four of the poles E_1, E_2, E_3, and E_4 (Fig. 307) lie in the same circle of north latitude, and the other four in the same circle of south latitude, each within one of the spherical triangles GPD.

Faces parallel to the following Pyramids of the Second Class have been observed in nature.

The form 1 $\frac{8}{7}$ 2; 2 $\breve{P}$ $\frac{8}{7}$ Naumann; 8 7 4 Miller; $B^1 B^{15} G^{\frac{15}{8}}$ Brooke and Levy.

Brookite . . $\lambda = 69° 51'$ $\mu = 46° 7'$

The form 1 $\frac{4}{3}$ 2; 2 $\breve{P}$ $\frac{4}{3}$ Naumann; 4 3 2 Miller; $B^1 B^7 G^{\frac{7}{4}}$ Brooke and Levy.

Brookite . . $\lambda = 68° 26'$ $\mu = 41° 42'$

The form 1 $\frac{3}{2}$ $\frac{3}{2}$; $\frac{3}{2}$ $\breve{P}$ $\frac{3}{2}$ Naumann; 3 2 2 Miller; $B^1 B^5 G^{\frac{5}{4}}$ Brooke and Levy.

Fayalite . . $\lambda = 64° 59'$ $\mu = 35° 52'$
Olivine . . $\lambda = 65° 12'$ $\mu = 35° 35'$
Staurolite . . $\lambda = 60° 37'$ $\mu = 54° 37'$

The form 1 $\frac{3}{2}$ 3; 3 $\breve{P}$ $\frac{3}{2}$ Naumann; 3 2 1 Miller; $B^1 B^5 G^{\frac{5}{2}}$ Brooke and Levy.

Datholite . . $\lambda = 63° 0'$ $\mu = 40° 6'$

The form 1 2 $\frac{1}{2}$; $\frac{1}{2}$ $\breve{P}$ 2 Naumann; 2 1 4 Miller; $B^1 B^3 G^{\frac{3}{8}}$ Brooke and Levy.

Baryte . . $\lambda = 37° 36'$ $\mu = 31° 33'$ | Leadhillite . $\lambda = 68° 51'$ $\mu = 41° 5'$

The form 1 2 $\frac{2}{3}$; $\frac{2}{3}\breve{P}$ 2 Naumann; 2 1 3 Miller; $B^1 B^3 G^{\frac{1}{2}}$ Brooke and Levy.

Antimonite .	$\lambda = 37°\ 21'$	$\mu = 26°\ 52'$	Topaz . .	$\lambda = 41°\ 4'$	$\mu = 43°\ 26'$
Sylvanite . .	$\lambda = 26°\ 42'$	$\mu = 35°\ 56'$			

The form 1 2 1; $\breve{P}$ 2 Naumann; 2 1 2 Miller; $B^1 B^3 G^{\frac{3}{4}}$ Brooke and Levy.

Anglesite . .	$\lambda = 56°\ 51'$	$\mu = 32°\ 27'$	Celestine . .	$\lambda = 56°\ 43'$	$\mu = 32°\ 38'$
Aragonite . .	$\lambda = 42°\ 45'$	$\mu = 38°\ 45'$	Chrysoberyl .	$\lambda = 46°\ 38'$	$\mu = 56°\ 47'$
Baryte . .	$\lambda = 57°\ 0'$	$\mu = 31°\ 33'$	Datholite . .	$\lambda = 30°\ 36'$	$\mu = 32°\ 17'$
Brookite . .	$\lambda = 47°\ 41'$	$\mu = 59°\ 17'$	Leadhillite .	$\lambda = 59°\ 10'$	$\mu = 41°\ 5'$

The form 1 2 $\frac{6}{5}$; $\frac{6}{5}\breve{P}$ 2 Naumann; 6 3 5 Miller; $B^1 B^3 G^{\frac{9}{10}}$ Brooke and Levy.

Manganite . $\lambda = 37°\ 14'$ $\mu = 30°\ 38'$

The form 1 2 $\frac{4}{3}$; $\frac{4}{3}\breve{P}$ 2 Naumann; 4 2 3 Miller; $B^1 B^3 G^1$ Brooke and Levy.

Datholite . . $\lambda = 38°\ 15'$ $\mu = 32°\ 17'$

The form 1 2 2; $2\breve{P}$ 2 Naumann; 2 1 1 Miller; $B^1 B^3 G^{\frac{3}{2}}$ Brooke and Levy.

Anglesite . .	$\lambda = 71°\ 55'$	$\mu = 32°\ 27'$	Manganite .	$\lambda = 51°\ 42'$	$\mu = 30°\ 38'$
Antimonite .	$\lambda = 66°\ 24'$	$\mu = 26°\ 52'$	Orpiment . .	$\lambda = 59°\ 21'$	$\mu = 39°\ 40'$
Aragonite . .	$\lambda = 61°\ 35'$	$\mu = 38°\ 45'$	Smithsonite .	$\lambda = 48°\ 44'$	$\mu = 32°\ 34'$
Brookite . .	$\lambda = 65°\ 32'$	$\mu = 59°\ 17'$	Sternbergite .	$\lambda = 65°\ 38'$	$\mu = 40°\ 37'$
Cerussite . .	$\lambda = 61°\ 52'$	$\mu = 50°\ 40'$	Sylvanite . .	$\lambda = 56°\ 28'$	$\mu = 35°\ 55'$
Chrysoberyl .	$\lambda = 59°\ 26'$	$\mu = 56°\ 47'$	Topaz . .	$\lambda = 69°\ 5'$	$\mu = 43°\ 26'$
Datholite . .	$\lambda = 49°\ 47'$	$\mu = 32°\ 17'$	Valentinite .	$\lambda = 77°\ 38'$	$\mu = 51°\ 45'$
Epistilbite .	$\lambda = 42°\ 21'$	$\mu = 50°\ 29'$	Wavellite . .	$\lambda = 46°\ 33'$	$\mu = 44°\ 44'$
Epsomite . .	$\lambda = 51°\ 59'$	$\mu = 26°\ 49'$	Wolfram . .	$\lambda = 63°\ 48'$	$\mu = 31°\ 35'$
Goslarite . .	$\lambda = 52°\ 11'$	$\mu = 26°\ 43'$			

The form 1 2 4; $4\breve{P}$ 2 Naumann; 4 2 1 Miller; $B^1 B^3 G^3$ or E_3 Brooke and Levy.

Datholite . . $\lambda = 67°\ 5'$ $\mu = 32°\ 17'$

The form 1 $\frac{5}{2}$ $\frac{5}{2}$; $\frac{5}{2}\breve{P}$ $\frac{5}{2}$ Naumann; 5 2 2 Miller; $B^1 B^{\frac{7}{3}} G^{\frac{7}{4}}$ Brooke and Levy.

Göthite . . $\lambda = 58°\ 52'$ $\mu = 23°\ 32'$

The form 1 $\frac{14}{5}$ $\frac{7}{9}$; $\frac{7}{9}\breve{P}$ $\frac{14}{5}$ Naumann; 14, 5, 18 Miller; $B^1 B^{\frac{19}{9}} G^{\frac{13}{36}}$ Brooke and Levy.

Brookite . . $\lambda = 38°\ 35'$ $\mu = 22°\ 59'$

The form 1 3 $\frac{3}{8}$; $\frac{3}{8}$P 3 Naumann; 3 1 8 Miller; $B^1 B^2 G^{\frac{1}{4}}$ Brooke and Levy.

Sylvanite . . $\lambda = 14°\ 27'$ $\mu = 25°\ 47'$

The form 1 3 $\frac{3}{5}$; $\frac{3}{5}\breve{P}$ 3 Naumann; 3 1 5 Miller; $B^1 B^2 G^{\frac{2}{5}}$ Brooke and Levy.

Celestine . .	$\lambda = 39°\ 56'$	$\mu = 23°\ 7'$	Topaz . .	$\lambda = 33°\ 57'$	$\mu = 32°\ 16'$
Sulphur . .	$\lambda = 50°\ 54'$	$\mu = 22°\ 22'$			

The form 1 3 $\frac{3}{4}$; $\frac{3}{4}\breve{P}$ 3 Naumann; 3 1 4 Miller; $B^1 B^2 G^{\frac{1}{2}}$ Brooke and Levy.

Bournonite . .	$\lambda = 35°\ 31'$	$\mu = 19°\ 34'$	Sylvanite . .	$\lambda = 26°\ 59'$	$\mu = 25°\ 47'$

The form 1 3 1; $\breve{P}$ 3 Naumann; 3 1 3 Miller; $B^1 B^2 G^{\frac{2}{3}}$ Brooke and Levy.

Antimonsilber .	$\lambda = 37°\ 47'$	$\mu = 30°\ 0'$	Sulphur . .	$\lambda = 64°\ 0'$	$\mu = 22°\ 22'$
Celestine . .	$\lambda = 54°\ 22'$	$\mu = 23°\ 7'$			

The form 1 3 $\frac{3}{2}$; $\frac{3}{2}\breve{P}$ 3 Naumann; 3 1 2 Miller; $B^1 B^2 G^1$ Brooke and Levy.

Baryte . .	$\lambda = 64°\ 49'$	$\mu = 22°\ 15'$	Sylvanite . .	$\lambda = 45°\ 31'$	$\mu = 25°\ 47'$
Celestine . .	$\lambda = 69°\ 50'$	$\mu = 23°\ 7'$			

The form 1 3 3; $3\breve{P}$ 3 Naumann; 3 1 1 Miller; $B^1 B^2 G^2$ or E_2 Brooke and Levy.

Cordierite . .	$\lambda = 62°\ 34'$	$\mu = 29°\ 35'$	Polykrase . .	$\lambda = 54°\ 18'$	$\mu = 42°\ 29'$
Niobite . .	$\lambda = 43°\ 26'$	$\mu = 21°\ 54'$			

The form 1 $\frac{10}{3}$ 5; $5\breve{P}$ $\frac{10}{3}$ Naumann; 10, 3, 2 Miller; $B^1 B^{\frac{13}{7}} G^{\frac{13}{4}}$ Brooke and Levy.

Brookite . . $\lambda = 72°\ 43'$ $\mu = 19°\ 37'$

The form $1\ \frac{7}{2}\ \frac{7}{2}$; $\frac{7}{2}\breve{P}\frac{7}{2}$ Naumann; 7 2 2 Miller; $B^1\ B^{\frac{9}{5}}\ G^{\frac{9}{4}}$ Brooke and Levy.
Brookite . . $\lambda = 74^\circ\ 1'$ $\mu = 18^\circ\ 45'$

The form 1 4 1; $\breve{P}\ 4$ Naumann; 4 1 4 Miller; $B^1\ B^{\frac{5}{3}}\ G^{\frac{5}{8}}$ Brooke and Levy.
Celestine . . $\lambda = 53^\circ\ 25'$ $\mu = 17^\circ\ 48'$ | Leadhillite . $\lambda = 54^\circ\ 2'$ $\mu = 23^\circ\ 33'$
Harmotome . $\lambda = 35^\circ\ 39'$ $\mu = 14^\circ\ 27'$

The form $1\ 4\ \frac{4}{3}$; $\frac{4}{3}\breve{P}\ 4$ Naumann; 4 1 3 Miller; $B^1\ B^{\frac{5}{3}}\ G^{\frac{5}{6}}$ Brooke and Levy.
Celestine . . $\lambda = 69^\circ\ 23'$ $\mu = 17^\circ\ 48'$ | Topaz . . $\lambda = 54^\circ\ 27'$ $\mu = 25^\circ\ 20'$

The form 1 4 2; $2\ \breve{P}\ 4$ Naumann; 4 1 2 Miller; $B^1\ B^{\frac{5}{3}}\ G^{\frac{5}{4}}$ Brooke and Levy.
Anglesite . . $\lambda = 73^\circ\ 7'$ $\mu = 17^\circ\ 38'$

The form 1 4 4; $4\ \breve{P}\ 4$ Naumann; 4 1 1 Miller; $B^1\ B^{\frac{5}{3}}\ G^{\frac{5}{2}}$ Brooke and Levy.
Datholite . . $\lambda = 64^\circ\ 33'$ $\mu = 17^\circ\ 32'$ | Smithsonite . $\lambda = 63^\circ\ 45'$ $\mu = 17^\circ\ 43'$

The form $1\ \frac{9}{2}\ \frac{9}{2}$; $\frac{9}{2}\breve{P}\frac{9}{2}$ Naumann; 9 2 2 Miller; $B^1\ B^{\frac{11}{7}}\ G^{\frac{11}{4}}$ Brooke and Levy.
Diaspore . . $\lambda = 69^\circ\ 58'$ $\mu = 13^\circ\ 22'$

The form 1 5 5; $5\ \breve{P}\ 5$ Naumann; 5 1 1 Miller; $B^1\ B^{\frac{3}{2}}\ G^3$ Brooke and Levy.
Brookite . . $\lambda = 78^\circ\ 22'$ $\mu = 13^\circ\ 22'$ | Datholite . . $\lambda = 68^\circ\ 48'$ $\mu = 14^\circ\ 10'$

The form 1 6 2; $2\ \breve{P}\ 6$ Naumann; 6 1 3 Miller; $B^1\ B^{\frac{7}{5}}\ G^{\frac{7}{6}}$ Brooke and Levy.
Niobite . . $\lambda = 60^\circ\ 49'$ $\mu = 11^\circ\ 22'$

Derived Rhombic Pyramid of the Third Class.—This pyramid is derived from the fundamental pyramid, by making the vertical axes CP_1 and CP_2 (Fig. 301) equal to m times the parameter CP (Fig. 302), where m may be any whole number or fraction, equal to, greater, or less than unity; and the greater horizontal axes CG_1, CG_2 (Fig. 301) equal to n times the parameter CH (Fig. 302) where n may be any whole number or fraction greater than unity.

Symbols.—The symbol for these pyramids is $n\ 1\ m$; Naumann's, $m\bar{P}n$; Miller's, $h\ k\ l$; Brooke and Levy's, $B^1\ B^{\frac{n+1}{n-1}}\ H^{\frac{m(n+1)}{2n}}$.

Inclination of Faces, position of Poles, &c.—If the symbols α, β, λ, μ, θ, ϕ, and ψ represent the same angles as in the case of the fundamental pyramid,

$$\tan\mu = n\cot\alpha \qquad \tan\lambda = \frac{m}{n}\tan\beta\sec\mu$$

$$\theta = 2\lambda \qquad \cos\frac{\phi}{2} = \frac{m}{n}\tan\beta\cos\lambda \qquad \sin\frac{\psi}{2} = m\,\frac{\tan\beta\cos\lambda}{\tan\alpha}$$

Four of the poles f_1, f_2, f_3, and f_4 (Fig. 307), lie in the same circle of north latitude, and the other four in the same circle of south latitude, whose polar distances are both equal to λ, each within one of the spherical triangles DPH.

Faces parallel to the following Pyramids of the Third Class have been observed in nature.

The form $\frac{4}{3}\ 1\ 4$; $4\bar{P}\frac{4}{3}$ Naumann; 3 4 1 Miller; $B^1\ B^7\ H^{\frac{7}{4}}$ Brooke and Levy.
Smithsonite . $\lambda = 70^\circ\ 42'$ $\mu = 59^\circ\ 35'$

The form $\frac{3}{2}\ 1\ \frac{1}{2}$; $\frac{1}{2}\bar{P}\frac{3}{2}$ Naumann; 2 3 6 Miller; $B^1\ B^5\ H^{\frac{5}{12}}$ Brooke and Levy.
Brookite . . $\lambda = 32^\circ\ 46'$ $\mu = 60^\circ\ 42'$

The form $\frac{3}{2}\ 1\ \frac{3}{4}$; $\frac{3}{4}\bar{P}\frac{3}{2}$ Naumann; 2 3 4 Miller; $B^1\ B^6\ H^{\frac{5}{8}}$ Brooke and Levy.
Anglesite . . $\lambda = 54^\circ\ 18'$ $\mu = 62^\circ\ 20'$

The form $\frac{3}{2}\ 1\ \frac{3}{2}$; $\frac{3}{2}\bar{P}\frac{3}{2}$ Naumann; 2 3 2 Miller; $B^1\ B^5\ H^{\frac{5}{4}}$ Brooke and Levy.
Brookite . . $\lambda = 62^\circ\ 37'$ $\mu = 60^\circ\ 42'$ | Tantalite . . $\lambda = 53^\circ\ 43'$ $\mu = 61^\circ\ 26'$

The form $\frac{5}{4}\,1\,\frac{5}{2}$; $\frac{5}{2}\bar{P}\frac{5}{4}$ Naumann; 4 5 2 Miller; $B^1 B^9 H^{\frac{9}{4}}$ Brooke and Levy.

Haidingerite .	$\lambda = 60° 48'$	$\mu = 56° 7'$

The form 2 1 1; $\bar{P}\,2$ Naumann; 1 2 2 Miller; $B^1 B^3 H^{\frac{3}{4}}$ Brooke and Levy.

Bournonite .	$\lambda = 46° 34'$	$\mu = 64° 52'$	Göthite . .	$\lambda = 36° 1'$	$\mu = 65° 20'$
Datholite . .	$\lambda = 34° 11'$	$\mu = 68° 24'$	Manganite .	$\lambda = 35° 1'$	$\mu = 67° 7'$
Diaspore . .	$\lambda = 34° 59'$	$\mu = 64° 57'$	Monticellite .	$\lambda = 55° 0'$	$\mu = 66° 27'$
Fayalite . .	$\lambda = 54° 4'$	$\mu = 65° 12'$	Olivine . .	$\lambda = 54° 15'$	$\mu = 65° 1'$

The form 2 1 2; $2\,\bar{P}\,2$ Naumann; 1 2 1 Miller; $B^1 B^3 H^{\frac{3}{2}}$ Brooke and Levy.

Bournonite. .	$\lambda = 64° 40'$	$\mu = 64° 52'$	Epsomite . .	$\lambda = 52° 9'$	$\mu = 63° 40'$
Cerussite . .	$\lambda = 74° 18'$	$\mu = 73° 2'$	Ilvaite . .	$\lambda = 54° 38'$	$\mu = 71° 6'$
Chrysoberyl .	$\lambda = 68° 28'$	$\mu = 76° 46'$	Smithsonite .	$\lambda = 52° 57'$	$\mu = 68° 38'$
Datholite . .	$\lambda = 53° 39'$	$\mu = 68° 24'$	Tantalite . .	$\lambda = 59° 52'$	$\mu = 67° 47'$

The form 2 1 4; $4\,\bar{P}\,2$ Naumann; 2 4 1 Miller; $B^1 B^3 H^3$, or A_3, Brooke and Levy.

Haidingerite .	$\lambda = 68° 47'$	$\mu = 67° 14'$

The form 3 1 1; $\bar{P}\,3$ Naumann; 1 3 3 Miller; $B^1 B^2 H^{\frac{2}{3}}$ Brooke and Levy.

Manganite .	$\lambda = 38° 51'$	$\mu = 74° 17'$

The form $3\,1\,\frac{3}{2}$; $\frac{3}{2}\bar{P}\,3$ Naumann; 1 3 2 Miller; $B^1 B^2 H^1$ Brooke and Levy.

Baryte . .	$\lambda = 68° 14'$	$\mu = 74° 48'$	Mispickel . .	$\lambda = 69° 42'$	$\mu = 77° 18'$
Datholite . .	$\lambda = 44° 25'$	$\mu = 75° 13'$	Sylvanite . .	$\lambda = 91° 56'$	$\mu = 77° 3'$

The form 3 1 3; $3\,\bar{P}\,3$ Naumann; 1 3 1 Miller; $B^1 B^2 H^2$, or A_2, Brooke and Levy.

Göthite . .	$\lambda = 64° 16'$	$\mu = 72° 59'$

The form $\frac{3}{2}\,1\,3$; $3\,\bar{P}\,\frac{3}{2}$ Naumann; 2 3 1 Miller; $B^1 B^5 H^{\frac{5}{2}}$ Brooke and Levy.

Smithsonite .	$\lambda = 64° 24'$	$\mu = 62° 27'$

The form 4 1 1; $\bar{P}\,4$ Naumann; 1 4 4 Miller; $B^1 B^{\frac{5}{3}} H^{\frac{5}{8}}$ Brooke and Levy.

Olivine . .	$\lambda = 52° 22'$	$\mu = 76° 54'$

Rhombic Sphenoid.—The *Rhombic Sphenoid*, or, *Irregular Tetrahedron*, is a *hemihedral form*, derived from the *double four-faced rhombic pyramid*, by the development of half its faces. It is bounded by four equal and similar triangular faces, each face, such as $B_1 B_8 B_6$ (Fig. 314), or $B_4 B_2 B_5$ (Fig. 315), being a scalene triangle. This solid has four three-faced solid angles, B_1, B_3, B_8, B_6 (Fig. 314), and B_2, B_4, B_5, B_7 (Fig. 315), each equal to one another; the six edges are equal to one another in pairs.

A sphenoid may be derived from every one of the pyramids previously described.

Fig. 314.

Fig. 315.

To draw the Rhombic Sphenoid.—Fig. 301 being drawn with axes P_1P_2, H_1H_2, and G_1G_2, of the requisite lengths for the pyramid; the points B_1, B_3, B_6, and B_8 being pricked off and joined, as in Fig. 314, will give the *positive sphenoid*, and the points B_2, B_4, B_5, and B_7, joined, as in Fig. 315, will give the *negative sphenoid.*

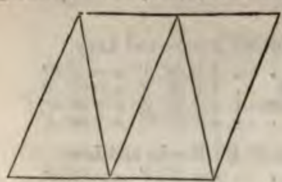


Fig. 316.

To Describe a Net for the Rhombic Sphenoid.—Let PGH (Fig. 312) be the face of the pyramid from which the sphenoid is derived; a triangle, each of whose sides is twice the corresponding side in PGH, will be a face of the derived sphenoid; and four such faces, arranged as in Fig. 316, will form the required net.

Principal Combinations of the Prismatic System.—Fig. 317. *Combination of a double four-faced rhombic pyramid with the faces of the right rectangular prism.* *a*, faces of the *pyramid*; *b*, faces of the *basal pinacoids* $\infty\ \infty\ 1$; 0 P Naumann; 0 0 1 Miller; P Brooke and Levy; replacing the solid angles P_1 and P_2 (Fig. 310) of the pyramid by planes.

c, faces of the *brachy-pinacoids* $1\ \infty\ \infty$; $\infty \breve{P} \infty$ Naumann; 1 0 0 Miller; G Brooke and Levy; replacing the solid angles G_1 and G_2 (Fig. 310) of the pyramid.

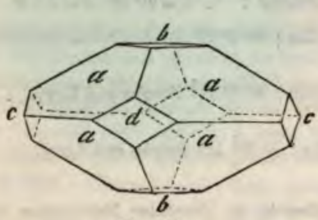


Fig. 317.

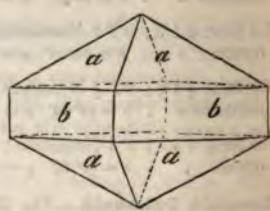


Fig. 318.

d, faces of the *macro-pinacoids* $\infty\ 1\ \infty$; $\infty \bar{P} \infty$ Naumann; 0 1 0 Miller; H Brooke and Levy; replacing the solid angles H_1 and H_2 (Fig. 310) of the pyramid.

Fig. 318. *Combination of the double four-faced rhombic pyramid with the faces of the right rhombic prism of the first order.*

If *a*, *a*, &c., represent the faces of the rhombic pyramid whose symbol is 1 1 1; P Naumann; 1 1 1 Miller; B Brooke and Levy; or of the pyramid 1 1 *m*, *m* P Naumann; *h h k* Miller; $B^{\frac{1}{m}}$ Brooke and Levy; *b*, *b*, &c., will represent the faces of the prism $1\ 1\ \infty$; ∞ P Naumann; 1 1 0 Miller; M Brooke and Levy; replacing the edges HG (Fig. 310) of the pyramid.

If *a*, *a*, &c., represent the faces of the pyramid *n* 1 *m*; $m \bar{P} n$ Naumann; *b*, *b*, &c., will represent the faces of the prism $n\ 1\ \infty$; $\infty \bar{P} n$ Naumann.

If *a*, *a*, &c., represent the faces of the pyramid 1 *n m*; $m \breve{P} n$ Naumann; *b*, *b*, &c., will represent the faces of the prism $1\ n\ \infty$; $\infty \breve{P} n$ Naumann.

Fig. 319. *Combination of the pyramid with a right rhombic prism of the second order.*

If *a*, *a*, &c., represent faces of the pyramid 1 1 *m*; *m* P Naumann; *b*, *b*, &c., will represent the faces of the prism $1\ \infty\ m$; $m \breve{P} \infty$ Naumann; replacing tde edges PG *(Fig. 310) of the pyramid.*

In a similar manner the faces of the prism $\infty m 1$; $m \bar{P} \infty$ Naumann; will replace the edges PH (Fig. 310) of the pyramid.

Fig. 320. *Combination of the pyramid with prisms of the first and second orders.*

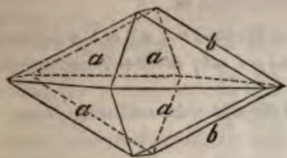


Fig. 319.

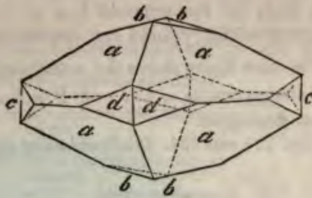


Fig. 320.

b, faces of the rhombic prism of the second order $1 \infty m$; $m \breve{P} \infty$ Naumann; replacing the solid angles P_1 P_2 (Fig. 310) of the pyramid *a*, *a*, &c., whose symbol is $1 1 m'$; m' P Naumann—where m' is less than m.

c, faces of the rhombic prism of the first order $1 n \infty$; $\infty \breve{P} m$ Naumann; replacing the solid angles G_1, G_2 (Fig. 310), of the pyramid *a*, *a*, &c., whose symbol is $1\ n'\ m$; $\breve{m}$ P n', where n' is less than n.

d, faces of the rhombic prism of the first order $n' 1 \infty$; ∞ $\bar{P} n$ Naumann; replacing the solid angles H_1 H_2 (Fig. 310) of the pyramid *a*, *a*, &c., whose symbol is $n' 1 m$; $m \bar{P} n'$ Naumann, where n' is greater than n.

Fig. 321. *Combination of the pyramid with the prisms of the second and third orders.*

b, faces of the prism of the third order ∞ $1 m$; $m \bar{P} \infty$ Naumann; replacing the solid angles P_1, P_2 (Fig. 310) of the pyramid *a*, *a*, &c., whose symbol is $1\ n\ m'$, or $m' \breve{P} n$ Naumann: or $n 1 m'$; $m' \bar{P} n$ Naumann, where m' is greater than m.

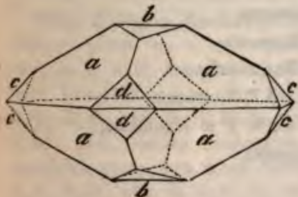


Fig. 321.

Fig. 322.

c, faces of the prism of the second order $1 \infty m$; $m \breve{P} \infty$ Naumann; replacing the solid angles G_1 G_2 (Fig. 310) of the preceding pyramids, where m' is less than m.

d, faces of the prism of the third order ∞ $1 m$; $m \bar{P} \infty$ Naumann; replacing the solid angles H_1 H_2 (Fig. 310) of the same pyramids, where m' is less than m.

Fig. 322. *Combinations of rhombic pyramids.*

a, faces of the pyramid $1\ n\ m$; $m \breve{P} n$ Naumann.

b, faces of the pyramid $1\ n\ m'$; $m'\ \breve{P}\ n$ Naumann; replacing the solid angl P_1 and P_2 of the pyramid *a*, *a*, &c., with a four-faced solid angle, where m' is l than *m*.

c, faces of the pyramid $1\ n\ m''$; $m''\ \breve{P}\ n$ Naumann; beveling the edges H (Fig. 310) of the pyramid *a*, *a*, &c, where m'' is greater than *m*.

The same figure shows the combinations of the pyramid $n\ 1\ m$; $m\ \bar{P}\ n$ Nauman with the pyramids $n\ 1\ m'$; $m'\ \bar{P}\ n$ Naumann, and $n\ 1\ m''$; $m''\ \bar{P}\ n$ Naumann und similar conditions.

Figs. 323 and 324. *Combinations of the prism of the first order with other forms.*

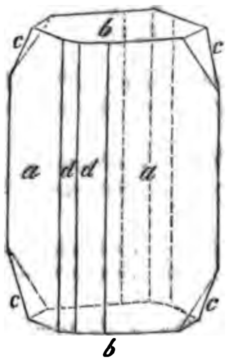


Fig. 323.

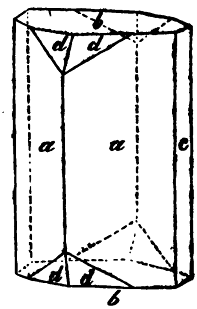


Fig. 324.

Fig. 323. *a*, faces of the prisms $1\ 1\ \infty$; ∞ P Naumann.
b, faces of the basal pinacoid $\infty\ \infty\ 1$; 0 P Naumann.
c, faces of the prism $1\ \infty\ 1$; $\breve{P}\ \infty$ Naumann.
d, faces of the prism $n\ 1\ \infty$; $\infty\ \bar{P}\ n$ Naumann.
Fig. 324. *a*, faces of the prism $n\ 1\ \infty$; $\infty\ \bar{P}\ n$ Naumann.
b, faces of the basal pinacoid, $\infty\ \infty\ 1$; 0 P Naumann.
c, faces of the brachy pinacoid, $1\ \infty\ \infty$; $\infty\ \breve{P}\ \infty$ Naumann.
d, faces of the pyramid $1\ 1\ 1$; P Naumann.

FIFTH SYSTEM—THE OBLIQUE.

This system is called the oblique, because its forms may be derived from the obliq prism, or oblique octahedron on a rhombic base. It has also been called the *monocli hedric*, *hemiprismatic*, *hemiorthotype*, *clinorhombic*, *hemihedric-rhombic*, and *two and o membered* system.

The forms of this system are the *oblique prism on a rectangular base*; two orders *prisms on rhombic bases*, a series of *right prisms on oblique rhombic bases*, and the *incli or oblique double four-faced pyramid or octahedron on a rhombic base.*

betical list of minerals belonging to the Oblique System, with the angular elements, from ich their typical forms and axes may be derived. Blanks are left in the cases where angular elements have not been determined.

	α °	α ′	β °	β ′	γ °	γ ′
!	—		—		—	
te	—		—		—	
e	63	40	51	15	35	45
bole (hornblende)	30	35	24	27	77	13
ergite (arseniate of kel)	55	9	53	57	59	11
sonite	50	35	24	27	77	13
	49	50	24	9	65	41
calcite	61	0	41	26	53	27
ite (sulphate of cobalt)	31	0	44	6	50	32
gen	63	5	54	29	62	41
ionite	63	25	51	30	35	48
erite	—		—		—	
te	49	50	24	19	65	41
ndite	63	43	51	41	35	17
lite (blue carbonate of pper)	45	4	47	17	58	4
rite	—		—		—	
ge	49	50	24	9	65	41
e	63	43	51	41	35	17
ine (cobalt bloom)	55	9	53	57	59	12
e	49	17	21	50	75	54
r	65	47	50	20	63	7
lende	62	35	53	51	50	34
ebenite (sulphuret of ver and antimony)	31	41	56	5	64	1
site	73	50	27	43	55	15
rite	37	23	30	53	58	10
m (sulphate of lime)	52	16	28	16	71	51
site	—		—		—	
ndite	43	53	47	32	73	28
e	64	0	36	48	37	43
ulite	42	43	25	14	52	50
stene	49	50	24	19	65	41
nite	34	1	51	28	41	13
s (red antimony)	—		—		—	
thine (lazulit)	29	25	58	50	50	10
lase (oblique prismatic seniate of copper)	24	18	56	12	32	15
ite	55	9	53	57	59	12

	α °	α ′	β °	β ′	γ °	γ ′
Laumonite	46	37	52	41	66	43
Lehmannite (chromate of lead)	39	2	38	59	59	29
Lepidolite	—		—		—	
Linarite (cupreous sulphate of lead)	74	25	28	20	50	26
Lunnite (hydrous phosphate of copper)	64	28	25	32	58	54
Margarite	—		—		—	
Malachite (green carbonate of copper)	—		—		—	
Melanterite (sulphate of iron)	31	53	43	47	50	46
Miargyrite	40	2	41	34	26	38
Mica	25	19	54	42	64	46
Mirabilite (sulphate of soda)	57	55	49	50	46	36
Monazite	39	20	36	54	59	41
Natron (carbonate of soda)	58	52	28	8	54	19
Pargasite	50	35	24	27	77	13
Pharmacolite (arseniate of lime)	54	58	28	16	73	50
Placodine	64	56	28	16	58	5
Plagionite	54	51	17	37	71	2
Realgar (red sulphuret of arsenic)	73	33	40	23	46	59
Rhodonite (siliciferous oxide of manganese)	49	50	24	9	65	41
Rhyacolite	65	37	50	29	63	19
Scheererite	—		—		—	
Scolezite (needlestone)	69	59	19	7	72	20
Sphene	34	27	60	27	68	8
Spodumene	49	50	60	40	65	33
Symplesite	—		—		—	
Tincal (borate of soda)	52	33	54	2	48	20
Triphyline	—		—		—	
Trona	—		—		—	
Vauquelinite	—		—		—	
Vivianite (phosphate of iron)	54	13	54	22	59	35
Wagnerite	63	25	44	42	56	3
Whewellite (oxalate of lime)	36	47	70	32	50	39
Woolastonite (tabular spar)	32	4	37	44	59	24
Zoisite	—		—		—	

he Oblique Rectangular Prism.—The oblique rectangular prism, or the ıe prism on a rectangular is a solid bounded by six two of these faces (Fig. 325), B_3 B_4 and B_5 B_6 B_7 B_8, are and similar rectangular elograms; two other faces, B_6 B_5 and B_4 B_3 B_7 B_8, are qual and similar rectangular elograms, differing in magni- rom the former pair; and the ning sides, B_1 B_4 B_8 B_5 and B_2 B_7, are equal and similar ie parallelograms.

is form is now generally ded as a combination of three

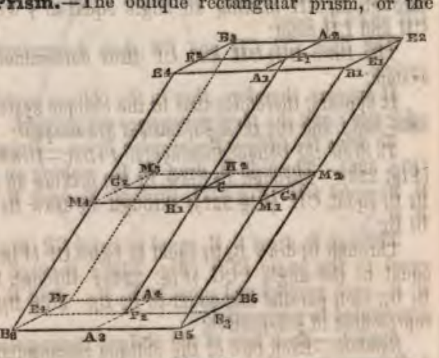


Fig. 325.

forms, each consisting of a pair of parallel faces, and sometimes appearing by itself in combination with other forms without the other two. B_1 B_2 B_3 B_4 and B_5 B_6 B_7 B_8 are then called the *basal pinacoids*, B_1 B_4 B_8 B_5 and B_2 B_3 B_7 B_6 the *clino-pinacoids*, and B_1 B_2 B_6 B_5 and B_4 B_3 B_7 B_8 the *ortho-pinacoids.*

Axes of the Oblique Prism and Oblique System.—Bisect the edges B_1 B_5, B_2 B_6, &c., Fig. 325, by the points M_1, M_2, M_3, and M_4; the edges B_1 B_2, B_4 B_3, &c., by the points E_1, E_2, E_3, and E_4; and the edges B_1 B_4, B_2 B_3, &c., by the points A_1, A_2, A_3, and A_4.

Join M_1 M_2 M_3 and M_4; E_1 E_2 and A_1 A_2 cutting in P_1; and E_3 E_4 and A_3 A_4 cutting in P_2.

Bisect M_1 M_2 and M_4 M_3 in G_1 and G_2; and also M_1 M_4 and M_2 M_3 in H_1 and H_2.

Join P_1 P_2, H_1 H_2, and G_1 G_2, cutting each other in C.

Then P_1 P_2, H_1 H_2, and G_1 G_2, are the three *axes of the prism*, and also *of the oblique system.*

P_1 P_2 is called the *chief or principal axis;* H_1 H_2 and G_1 G_2 the ***secondary axes.*** H_1 H_2 is the *ortho-diagonal*, and G_1 G_2 the *clino-diagonal* of Naumann.

P_1 P_2 and G_1 G_2 are inclined to one another, at some angle greater or less than, but never equal to, a right angle; H_1 H_2 is perpendicular to both P_1 P_2 and G_1 G_2, and consequently to the plane in which they lie.

Parameters.—The semi-axes CP_1, CG_1, and CH_1, are the *parameters* of the oblique system; the length of CG_1 is perfectly arbitrary, but its length once chosen, the magnitude of CP_1 and CH_1 for any particular mineral depends upon the angular elements previously given.

To determine CP and CH. Draw CG (Fig. 326) of any convenient length.

Fig. 326.

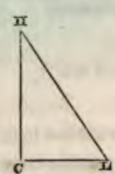


Fig. 327.

Then if α, β and γ be the three angles given as the angular elements of any particular substance,

Draw CP making an angle equal to $180^\circ - (\alpha + \beta)$ with CG, and through G the line GP, making an angle equal to β with CG.

Let CP and GP meet in the point P; through C draw CL perpendicular to PG.

Then (Fig. 327) draw CL equal to CL (Fig. 326). Through C draw CH perpendicular to CL, and through L, LH making an angle equal to γ with CL. Let H be the point where CH and LH meet.

The lines CG, CH and CP thus determined are the *parameters* of the oblique system.

It appears, therefore, that in the oblique system *one axis only is perpendicular to the other two;* and the *three parameters are unequal.*

To draw the Oblique Rectangular Prism.—Draw B_8 B_5 (Fig. 325) equal to twice CG (Fig. 326). Through B_8 draw B_8 B_7, making an angle of about 30° with B_8 B_7; make B_8 B_7 equal CH (Fig 327), through B_5 draw B_5 B_6 equal and parallel to B_8 B_7, join B_7 B_6.

Through B_8 draw B_8 B_4 equal to twice CP (Fig. 326), and making the angle B_4 B_8 B_5 equal to the angle PCG (Fig. 326); through B_5, B_6 and B_7 draw B_5 B_1, B_6 B_2, and B_7 B_3, each parallel and equal to B_8 B_4. Join B_1, B_2, B_3 and B_4, and the prism will be represented in perspective.

Symbols.—Each face of the oblique rectangular prism cuts one of the three axes, at a distance from their centre, equal to the length of one of the parameters, and is parallel to the other two axes.

The two *basal pinacoids* $B_1\ B_2\ B_3\ B_4$ and $B_5\ B_6\ B_7\ B_8$ cut the axis $P_1\ P_2$ in the points P_1 and P_2, and are parallel to the axes $H_1\ H_2$ and $G_1\ G_2$.

The symbol which represents the relation of these faces to the axes is $\infty\ \infty\ 1$.

Naumann's symbol is $0\,P$; Miller's, $0\,0\,1$; Brooke and Levy's modification of Haüy is P, when they regard the oblique rhombic prism as the primitive form of the crystal.

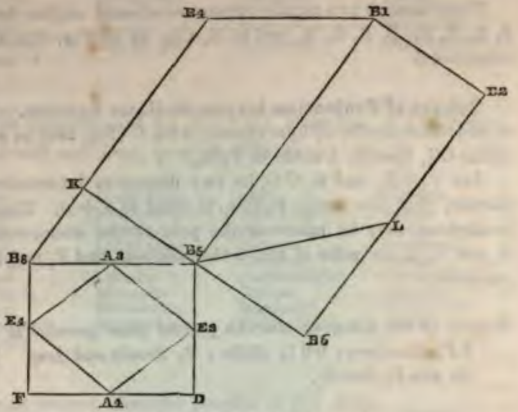


Fig. 328.

The two *ortho-pinacoids* $B_1\ B_2\ B_6\ B_5$ and $B_4\ B_3\ B_7\ B_8$ cut the axis $G_1\ G_2$ in the points G_1 and G_2, and are parallel to the axes $H_1\ H_2$ and $P_1\ P_2$. The symbol which represents this relation is $1\ \infty\ \infty$.

Naumann's symbol is $\infty\,P\,\infty$; Miller's $1\,0\,0$; Brooke and Levy's H.

The two *clino-pinacoids* $B_1\ B_4\ B_8\ B_5$ and $B_2\ B_3\ B_7\ B_6$ cut the axis $H_1\ H_2$ in the points H_1 and H_2, and are parallel to the axes $P_1\ P_2$ and $G_1\ G_2$. The symbol which represents this relation is $\infty\ 1\ \infty$.

Naumann's symbol is $(\infty\,P\,\infty)$; Miller's $0\,1\,0$; Brooke and Levy's G.

To describe a Net for the Oblique Rectangular Prism. — Describe a parallelogram

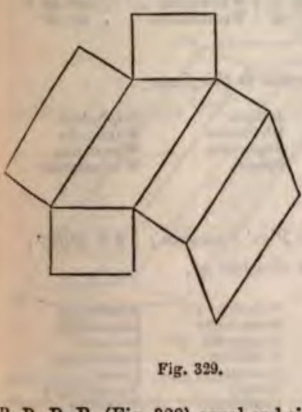


Fig. 329.

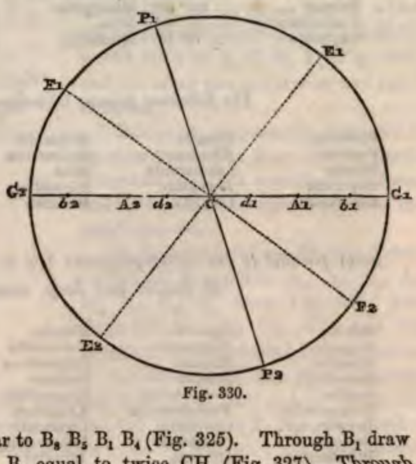


Fig. 330.

$B_8\ B_5\ B_1\ B_4$ (Fig. 328) equal and similar to $B_8\ B_5\ B_1\ B_4$ (Fig. 325). Through B_1 draw $B_1\ B_2$ perpendicular to $B_1\ B_5$, make $B_1\ B_2$ equal to twice CH (Fig. 327). Through

B_5 draw $B_8 B_6$ perpendicular to $B_1 B_5$, making $B_8 B_6$ equal to $B_1 B_2$, and join $B_2 B_6$. Through B_8 draw B_8 F perpendicular to $B_8 B_5$, and equal to $B_5 B_8$, and through B_5, B_5 D parallel and equal to B_8 F. Join FD.

Then arrange two parallelograms equal and similar to each of the parallelograms $B_1 B_5 B_8 B_4$, $B_1 B_2 B_6 B_5$, and $B_8 B_5$ CD, as in Fig. 329, and the required net will be constructed.

Sphere of Projection for the Oblique System.—To draw a map of the sphere of projection for the oblique system, with C (Fig. 330) as a centre, and any convenient radius CG_1 describe a circle $G_1 P_1 G_2$.

Let $P_1 C P_2$, and $G_1 C G_2$ be two diameters intersecting one another in such a manner, that the angle $P_1 C G_1$ is equal to $\alpha + \beta$. Then C, the north pole of the hemisphere, may be taken as the pole of the *clino-pinacoid* $B_1 B_4 B_8 B_5$ (Fig. 325), G_1 and G_2 as the poles of the *ortho-pinacoids*, and P_1 and P_2 as the poles of the *basal pinacoids*.

Crystals of the following minerals present faces parallel to the Basal Pinacoids ∞ ∞ 1; 0 P, *Naumann*; 0 0 1, *Miller*; P, *Brooke and Levy*. *The angle is the longitude of the pole* P_1 *from* G_1.

Allanite	114° 55′	Glauberite	68° 16′	Monazite	76° 14′
Amphibole	75° 2′	Heulandite	91° 25′	Pargasite	75° 2′
Augite	73° 59′	Humite	100° 48′	Pharmacolite	83° 14′
Barytocalcite	102° 26′	Johannite	85° 29′	Plagionite	72° 28′
Bieberite	75° 6′	Kermes	37° 45′	Realgar	113° 55′
Botryogen	117° 34′	Klaprothine	88° 15′	Rhodonite	73° 59′
Bragationite	114° 55′	Klinoclase	80° 30′	Rhyacolite	116° 6′
Brewsterite	86° 20′	Lehmannite	78° 1′	Sphene	94° 54′
Bronzite	73° 59′	Lepidolite, undetermined		Spodumene	110° 30′
Bucklandite	114° 55′	Linarite	102° 45′	Tincal	106° 35′
Chessylite	92° 21′	Lunnite	90° 0′	Triphyline, undetermined.	
Epidote	115° 24′	Malachite	61° 45′	Vauquelinite	,,
Euclase	71° 7′	Melanterite	75° 40′	Vivianite	108° 35′
Felspar	116° 7′	Miargyrite	81° 36′	Wagnerite	108° 7′
Freieslebenite	87° 46′	Mica	80° 1′	Whewellite	107° 19′
Gaylusite	78° 27′	Mirabilite	107° 45′	Woolastonite	69° 48′

The following present Cleavages parallel to this form.

Bronzite	Humite	*Malachite*	*Realgar*	*Triphyline*
Epidote	*Klinocase*	*Melanterite*	Rhodonite	Wagnerite
Felspar	Lehmannite	*Mica*	*Rhyacolite*	Whewellite
Gaylusite	*Lepidolite*	*Mirabilite*	Sphene	Woolastonite
Glauberite	Linarite	*Monazite*		

Faces parallel to the Ortho-pinacoids 1 ∞ ∞; ∞ P ∞ *Naumann*; 1 0 0 *Miller*; H *Brooke and Levy, occur in Crystals of*

Acmite	Epidote	Humite	Malachite	Rhodonite
Algerite	Erythrine	Hureaulite	Melanterite	Rhyacolite
Allanite	Euclase	Hyperstene	Miargyrite	Scolezite
Amphibole	Felspar	Kermes	Mirabilite	Spodumene
Augite	Feuerblende	Klaprothine	Monazite	Tincal
Bragationite	Freieslebenite	Klinoclase	Natron	Vauquelinite
Brewsterite	Gaylusite	Laumonite	Placodine	Vivianite
Bronzite	Glauberite	Lehmannite	Plagionite	Wagnerite
Bucklandite	Gypsum	Linarite	Realgar	Woolastonite
Chessylite	Heulandite	Lunnite		

The following present Cleavages parallel to this form.

Acmite	*Epidote*	Laumonite	Mirabilite	*Spodumene*
Amphibole	Erythrine	Lehmannite	Monazite	*Tincal*
Augite	Euclase	*Linarite*	Placodine	Vivianite
Brewsterite	Gypsum	Lunnite	Realgar	Wagnerite
Bronzite	*Hyperstene*	Miargyrite	Rhodonite	Woolastonite
Chessylite	Kermes			

Faces parallel to the Clino-pinacoids $\infty\ 1\ \infty$; $(\infty \mathrm{P} \infty)$ *Naumann*; 0 1 0 *Miller*; G *Brooke and Levy, occur in Crystals of*

Acmite	Epidote	Klaprothine	Mica	Scolezite
Algerite	Erythrine	Köttigite	Mirabilite	Sphene
Amphibole	Euclase	Laumonite	Monazite	Spodumene
Annabergite	Felspar	Lehmannite	Natron	Symplesite
Arfvedsonite	Feuerblende	Lepidolite	Pargasite	Tincal
Augite	Gypsum	Linarite	Pharmacolite	Triphyline
Botryogen	Heulandite	Malachite	Realgar	Vivianite
Brewsterite	Humite	Melanterite	Rhodonite	Whewellite
Bronzite	Hyperstene	Miargyrite	Rhyacolite	Zoisite
Chessylite	Johannite			

The following present Cleavages parallel to this form.

Acmite	*Erythrine*	*Köttigite*	Monazite	Rhyacolite
Amphibole	*Euclase*	*Laumonite*	Natron	*Symplesite*
Annabergite	Felspar	Lepidolite	Pargasite	Tincal
Arfvedsonite	*Gypsum*	*Malachite*	*Pharmacolite*	Triphyline
Augite	*Heulandite*	Mica	Realgar	*Vivianite*
Brewsterite	Hyperstene	Mirabilite	Rhodonite	Whewellite
Bronzite				

Oblique Rhombic Prism of the First Order.—The *oblique rhombic prism*, or the *oblique prism on a rhombic base*, is a solid bounded by six faces, four of which are similar and equal oblique parallelograms, such as $A_1\ E_1\ E_3\ A_3$ (Fig. 331), and the other two are similar and equal rhombs.

Fig. 331.

This prism is generally regarded as an open form; the four oblique parallelograms are then considered its faces, and the two rhombs which inclose it the *basal pinacoids*.

To Draw the Oblique Rhombic Prism.—Pick off the points A_1, A_2, A_3, A_4, E_1, E_2, E_3, E_4, from Fig. 325; join these points as in Fig. 331, and the prism will be represented in perspective.

Symbols.—Each face of this prism, considered as an open form, cuts two of the axes $G_1\ G_2$ (Fig. 325) and $H_1\ H_2$, at the extremities of their parameters, and is parallel to the third axis $P_1\ P_2$. The symbol representing this property is $1\ 1\ \infty$; Naumann's is ∞ P, Miller's 1 1 0, Brooke and Levy's M.

To Describe a Net for the Oblique Rhombic Prism of the First Order.—Bisect B_5 B_8 (Fig. 328) and F D by the points A_3 A_4, also the lines B_5 D and B_8 F by E_3 and E_4. Join E_3, A_3, E_4, and A_4; then E_4 A_3 E_3 A_4 will be the rhomb which forms the base of the prism.

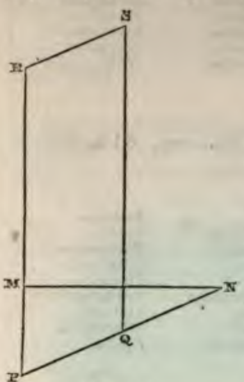


Fig. 332.

Through B_5 (Fig. 328) draw B_5 K perpendicular to B_4 B_8. In B_6 B_2 take B_6 L equal B_5 K. Join B_5 L.

Then (Fig. 332) draw M N equal B_5 L (Fig. 328), M P perpendicular to M N and equal B_8 K (Fig. 328).

Join P N, and bisect it in Q; produce P M to R, and make P R equal B_5 B_1 (Fig. 325). Through Q draw Q S parallel and equal to P R; and join R S.

P Q R S will be one of the four oblique parallelograms forming one of the sides of the prism. Four such parallelograms, and two rhombs equal A_4 E_3 A_3 E_4, arranged as in Fig. 333, will form the required net.


Fig. 333.

Poles of the Oblique Rhombic Prism of the First Order on the Sphere of Projection.—The four poles of this form lie in the zone or meridian G_1 C G_2 (Fig. 330): two, A_1 and A_2 (Fig. 330), where the circle of north latitude, whose polar distance from C the north pole is λ, cuts the zone G_1 C G_2; and two where the circle of south latitude, whose polar distance from the south pole is λ, cuts the same zone. λ is determined from the formula—

$$\tan. \lambda = \sin. \beta \tan. \gamma \operatorname{cosec} (\alpha + \beta),$$

where α, β, and γ are the three angles previously given as the angular elements, for the substance, whose poles for this form are required.

Poles parallel to the Oblique Rhombic Prism, 1 1 ∞; ∞ P *Naumann;* 1 1 0 *Miller;* M *Brooke and Levy, occur in the following Minerals. The angle is the angle* λ, *which determines the Latitude of their Poles.*

Acmite	43° 28′	Glauberite	41° 40′	Monazite	46° 35′
Algerite	47° 0′	Gypsum	55° 41′	Natron	38° 14′
Amphibole	62° 6′	Heulandite	68° 2′	Pargasite	62° 15′
Arfvedsonite	62° 6′	Humite	25° 15′	Pharmacolite	58° 42′
Augite	43° 33′	Hureaulite	31° 15′	Placodine	32° 16′
Barytocalcite	42° 20′	Hyperstene	43° 15′	Realgar	37° 13′
Bieberite	41° 10′	Johannite	34° 30′	Rhodonite	43° 33′
Botryogen	59° 58′	Klaprothine	45° 45′	Scolezite	45° 48′
Brewsterite	68° 0′	Klinoclase	28° 0′	Sphene	66° 54′
Bronzite	43° 33′	Laumonite	43° 8′	Spodumene	43° 30′
Bucklandite	31° 34′	Lehmannite	46° 52′	Tincal	43° 30′
Chessylite	49° 46′	Lepidolite	59° 30′	Triphyline	66° 0′
Epidote	31° 34′	Linarite	30° 30′	Vivianite	55° 36′
Euclase	57° 25′	Malachite	53° 40′	Wagnerite	47° 42′
Felspar	59° 24′	Melanterite	41° 10′	Whewellite	50° 18′
Feuerblende	69° 36′	Miargyrite	19° 49′	Woolastonite	47° 47′
Freieslebenite	59° 36′	Mica	60° 23′	Zoisite	58° 8′
Gaylussite	34° 25′	Mirabilite	40° 19′		

The following present Cleavages parallel to this prism.

Acmite	Felspar	Laumonite	*Pargasite*	Sphene
Amphibole	Freieslebenite	*Lehmannite*	Placodine	Spodumene
Arfvedsonite	*Gaylussite*	Lepidolite	Realgar	Tincal
Augite	Glauberite	Melanterite	Rhodonite	Triphyline
Botryogen	Hyperstene	Mica	*Scolezite*	Whewellite
Chessylite	Johannite	Natron		

Oblique Rhombic Prisms derived from the Oblique Rhombic Prism of the First Order 1 1 ∞, *by increasing the axis* CH_1, *or the Orthodiagonal* H_1H_2.—These prisms will be similar in magnitude and position to the prism 1 1 ∞ (Fig. 331) from which they are derived, but will differ in magnitude. To draw these prisms and describe their nets, we must make H_1 H_2 (Fig. 325) equal to n times the parameter CH (Fig. 327), where n may be any whole number or fraction greater than unity. Making this alteration in Fig. 325, the points A_1, A_2, A_3, A_4, and E_1, E_2, E_3, E_4, will give the angular points of the derived prism. From Fig. 325 so altered, the net for the derived prism may be obtained in the way described for the prism 1 1 ∞.

The symbol which represents the relation of this derived prism to the axes of the oblique system is 1 n ∞; Naumann's is ∞ P n; Miller's k h o; Brooke and Levy's $H^{\frac{n+1}{n-1}}$.

Position of the Poles of these derived Prisms on the Sphere of Projection.—The four poles of these prisms lie in the zone or meridian G_1 C G_2 (Fig. 330). Two where the circle of north latitude, whose polar distance from C, the north pole, is λ, cuts the zone G_1 C G_2, these points b_1 and b_2 always lie between A_1 G_1 and A_2 G_2; the other two poles will be where the circle of latitude, whose south polar distance is λ, cuts the same zone. λ is determined from the formula

$$\tan \lambda = n \sin \beta \tan \gamma \operatorname{cosec} (\alpha + \beta).$$

Faces parallel to the following forms of these Prisms have been observed; the angle given for each Mineral is λ.

The form 1 $\frac{4}{3}$ ∞; ∞ P $\frac{4}{3}$ Naumann; 4 3 0 Miller; H^7 Brooke and Levy.

Euclase . . .	64° 24′	Freieslebenite .	66° 24′	Realgar . .	45° 20′

The form 1 $\frac{3}{2}$ ∞; ∞ P $\frac{3}{2}$ Naumann; 3 2 0 Miller; H^5 Brooke and Levy.

Chessylite . .	60° 35′	Euclase . . .	66° 55′	Placodine . .	43° 28′
Erythrine . .	65° 5′	Lehmannite . .	58° 1′	Wagnerite . .	58° 46′

The form 1 2 ∞; ∞ P 2 Naumann; 2 1 0 Miller; H^3 Brooke and Levy.

Amphibole . .	62° 15′	Euclase . . .	72° 17′	Realgar . .	56° 38′
Botryogen . .	40° 52′	Lehmannite . .	64° 54′	Wagnerite . .	65° 32′
Chessylite . .	67° 4′	Mirabilite . .	22° 59′	Zoisite . . .	72° 44′
Epidote . . .	50° 51′				

Botryogen has a cleavage parallel to this form.

The form 1 $\frac{5}{2}$ ∞; ∞ P $\frac{5}{2}$ Naumann; 5 2 0 Miller; $H^{\frac{7}{3}}$ Brooke and Levy.

Realgar . . .	62° 14′

The form 1 3 ∞; ∞ P 3 Naumann; 3 1 0 Miller; H^2 Brooke and Levy.

Amphibole . .	80° 3′	Freieslebenite .	78° 56′	Pharmacolite .	78° 33′
Augite . . .	70° 40′	Miargyrite . .	45° 15′	Vivianite . .	77° 7′
Felspar . . .	29° 25′				

Oblique Rhombic Prisms derived from the Oblique Prism 1 1 ∞, *by increasing the axis* CG_1, *or the Clino-diagonal* G_1G_2.—These prisms also will be similar in magnitude and position to the prism 1 1 ∞ (Fig. 331), from which they are derived; they may be drawn and their nets described by making CG_1 and CG_2 (Fig. 325) equal to n times the parameter CG (Fig. 326), where n may be any whole number or fraction greater than unity.

The symbol which represents the relation of the derived prism to the axes of the oblique system is $n\ 1\ \infty$; Naumann's is $(\infty\ P\ n)$; Miller's $h\ k\ o$; Brooke and Levy's $G^{\frac{n+1}{n-1}}$.

Position of the Poles of these derived Prisms on the Sphere of Projection.—The four poles of these prisms lie in the zone or meridian G_1CG_2 (Fig. 330), two where the circle of north latitude, whose polar distance from C, the north pole, is λ, cuts the zone G_1CG_2; these points d_1 and d_2 always lie detween CA_1 and CA_2; the other two poles will be where the circle of latitude, whose south polar distance is λ, cuts the same zone. λ is determined from the formula

$$\tan \lambda = \frac{1}{n} \sin \beta \tan \gamma \operatorname{cosec} (\alpha + \beta).$$

Faces parallel to the following forms of these Prisms have been observed; the angle given for each Mineral is λ.

The form $\frac{6}{5}\ 1\ \infty$; $(\infty\ P\ \frac{6}{5})$Naumann; 5 6 0 Miller; G^{11} Brooke and Levy.

Freieslebenite	54° 51′

The form $\frac{4}{3}\ 1\ \infty$; $(\infty\ P\ \frac{4}{3})$ Naumann; 3 4 0 Miller; G^{7} Brooke and Levy.

Erythrine	47° 6′

The form $\frac{3}{2}\ 1\ \infty$; $(\infty\ P\ \frac{3}{2})$ Naumann; 2 3 0 Miller; G^{5} Brooke and Levy.

Realgar	26° 51′

The form $\frac{5}{3}\ 1\ \infty$; $(\infty\ P\ \frac{5}{3})$ Naumann; 3 5 0 Miller; G^{4} Brooke and Levy.

Freieslebenite	45° 39′

The form $2\ 1\ \infty$; $(\infty\ P\ 2)$ Naumann; 1 2 0 Miller; G^{3} Brooke and Levy.

Augite	25° 25′	Gypsum	36° 12′	Monazite	27° 51′
Brewsterite	51° 4′	Lehmannite	28° 5′	Wagnerite	28° 47′
Chessylite	30° 35′	Lunnite	19° 28′	Whewellite	31° 3′
Freieslebenite	40° 26′				

Freieslebenite and Wagnerite have cleavages parallel to this form.

The form $3\ 1\ \infty$; $(\infty\ P\ 3)$ Naumann; 1 3 0 Miller; G^{2} Brooke and Levy.

Amphibole	32° 21′	Barytocalcite	16° 27′	Sphene	38° 1′
Augite	17° 35′	Gypsum	26° 1′	Spodumene	17° 33′

Right Prism on an Oblique Rhombic Base.—This prism has two faces $A_1\,A_2\,M_2\,M_1$ (Fig. 334) $A_3\,A_4\,M_3\,M_4$, which are similar and equal rectangular parallelograms, two other faces $A_1\,A_2\,M_3\,M_4$ and $M_1\,M_2\,A_4\,A_3$ also rectangular parallelograms, and similar and equal to each other, all inclosed by the two faces $A_1\,M_1\,A_3\,M_4$ and $M_2\,A_2\,M_3\,A_4$ which are similar and equal oblique parallelograms.

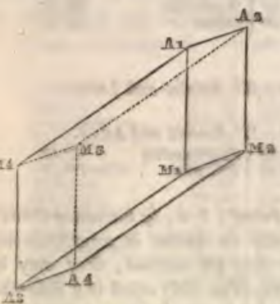


Fig. 334.

The four rectangular parallelograms are the faces of this prism when it is regarded as an open form; the oblique parallelograms which inclose it are then the faces of the clino-pinacoids.

The four faces of this prism cut the two axes $P_1\,P_2$ and $G_1\,G_2$, in the points P and G, and are parallel to the third axis $H_1\,H_2$ (Fig. 325).

The two faces $A_1\,A_2\,M_2\,M_1$ and $M_4\,M_3\,A_4\,A_3$ are called the *positive*; and $A_1\,A_2\,M_4\,M_3$, $M_1\,M_2\,A_3\,A_4$ the *negative ortho-domes*.

To draw this prism we have only to prick off the points A_1, A_2, A_3, A_4, E_1, E_2, E_3, and E_4 (Fig. 325), and join them as in Fig. 334.

Symbols.—The symbol which represents the relation of this prism to the axes of the oblique system is $1 \infty 1$; Naumann's is $P \infty$, Miller's 1 0 1, Brooke and Levy's O^1, for the *positive ortho-domes*; and $\bar{1} \infty 1$, $-P \infty$ Naumann, $\bar{1}$ 0 1 Miller, A^1 Brooke and Levy, for the *negative ortho-domes*.

Net for the Right Prism on an Oblique Rhombic Base.—Describe two oblique rhombic parallelograms similar and equal to $A_1 M_1 A_3 M_4$ (Fig. 334), two rectangular parallelograms, having their breadth equal to $A_1 M_1$ and length to twice $M_1 A_1$, and two other rectangular parallelograms of the same length, but having their breadth equal to $M_1 A_3$; arrange these six parallelograms as in Fig. 335, and the net will be constructed.

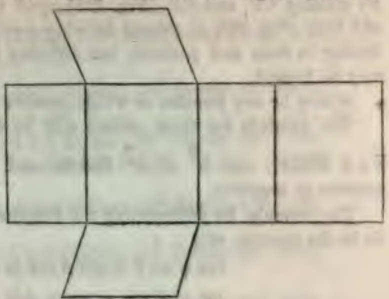


Fig. 335.

Position of the Poles of the Prism on an Oblique Rhombic Base on the Sphere of Projection.—The four poles of this prism always lie in the equator, $E_1 P_1 E_2$, Fig. 330, the poles of the positive ortho-domes between $P_1 G_1$ and $P_2 G_2$, the arc $G_1 E_1$ being equal to the arc $G_2 E_2$; F_1, F_2 the poles of the negative ortho-domes between $P_1 G_2$ and $P_2 G_1$, the arc $G_1 F_1$ being equal to $G_2 F_2$.

To determine the longitude of E_1 from G_1, we have the following formulæ:—

If ϕ be such an angle that $\tan \phi = \sin \beta \cos (\alpha + \beta) \operatorname{cosec} \alpha$,

And μ such an angle that $\cot \mu = \sin \phi \operatorname{cosec} (45^\circ + \phi) \sin 45^\circ \tan (\alpha + \beta)$.

Then longitude of E_1 equals $\mu + \alpha + \beta - 90$.

To determine the longitude of F_1, we have

$$\tan \phi = - \sin \beta \cos (\alpha + \beta) \operatorname{cosec} \alpha,$$

$$\text{And } \cot \mu = \sin \phi \operatorname{cosec} (45^\circ + \phi) \sin 45^\circ \tan (\alpha + \beta).$$

Faces parallel to the Right Prism on a Rhombic Base have been observed in the following Minerals; the angle is that of their longitude.

The form $1 \infty 1$; $P \infty$ Naumann; 1 0 1 Miller; $O^{\frac{1}{2}}$ Brooke and Levy.

Allanite	63° 40′	Freieslebenite	31° 41′	Monazite	39° 20′
Amphibole	50° 35′	Gypsum	52° 16′	Natron	58° 52′
Augite	49° 50′	Humite	64° 0′	Placodine	64° 56′
Barytocalcite	61° 0′	Johannite	34° 1′	Realgar	73° 33′
Bieberite	31° 0′	Kermes	72° 6′	Rhyacolite	65° 37′
Botryogen	63° 5′	Klaprothine	29° 25′	Sphene	34° 27′
Bragationite	63° 25′	Klinoclase	24° 18′	Triphyline	undet.
Chessylite	45° 4′	Lehmannite	39° 2′	Vauquelinite	undet.
Epidote	63° 43′	Melanterite	31° 53′	Vivianite	54° 13′
Erythrine	55° 9′	Miargyrite	40° 2′	Wagnerite	63° 25′
Euclase	49° 17′	Mirabilite	57° 55′	Whewellite	30° 47′
Felspar	65° 48′				

Euclase has a cleavage parallel to this form.

The form $\bar{1}$ ∞ 1; —P ∞ Naumann; $\bar{1}$ 0 1 Miller; A^2 Brooke and Levy.

Amphibole	106° 2′	Hypersthene	105° 7′	Natron	126° 32′
Augite	105° 7′	Klaprothine	149° 45′	Placodine	120° 5′
Barytocalcite	134° 52′	Lehmannite	128° 58′	Sphene	148° 28′
Bieberite	138° 31′	Melanterite	137° 38′	Triphyline	undet.
Chessylite	137° 13′	Miargyrite	131° 46′	Vivianite	144° 20′
Gypsum	113° 46′	Monazite	126° 8′		

Barytocalcite has a cleavage parallel to this form.

Prisms derived from the Right Prism on an Oblique Rhombic Base.—By making CP_1 and CP_2 (Fig. 325) equal to m times the parameter CP (Fig. 326); and from (Fig. 325) so altered deriving a prism, as in Fig. 334, a new series of prisms, similar in form and position, but differing in magnitude from the prism (Fig. 334), may be formed.

m may be any fraction or whole number greater or less than unity.

The symbols for these prisms will be $\pm 1, \infty, m$; $\pm m$ P ∞ Naumann; $h\,o\,k$, or $\bar{h}\,o\,k$ Miller; and $O^{\frac{m}{2}}$ or $A^{\frac{m}{2}}$ Brooke and Levy, according as the ortho-domes are positive or negative.

The formulæ for determining the longitude for the poles of these prisms, which all lie in the equator, are,

$$\tan \phi = \pm m \sin \beta \cos (\alpha + \beta) \operatorname{cosec} \alpha$$

$$\cot \mu = \sin \phi \operatorname{cosec} (45 + \phi) \sin 45 \tan (\alpha + \beta)$$

and longitude equal to $\mu + \alpha + \beta - 90$.

Faces parallel to these derived Prisms, with the following angles for determining the Longitude of their Poles, have been observed in nature.

The form 1 ∞ $\frac{1}{8}$; $\frac{1}{8}$ P ∞ Naumann; 1 0 8 Miller; $O^{\frac{1}{16}}$ Brooke and Levy.

Chessylite	84° 55′	Linarite	99° 16′

The form 1 ∞ $\frac{1}{5}$; $\frac{1}{5}$ P ∞ Naumann; 1 0 5 Miller; $O^{\frac{1}{10}}$ Brooke and Levy.

Chessylite	80° 32′

The form 1 ∞ $\frac{1}{3}$; $\frac{1}{3}$ P ∞ Naumann; 1 0 3 Miller; $O^{\frac{1}{6}}$ Brooke and Levy.

Bucklandite	98° 38′	Kermes	102° 9′	Melanterite	54° 46′
Epidote	98° 38′	Klaprothine	58° 30′	Vivianite	89° 5′
Erythrine	89° 52′				

Erythrine has a cleavage parallel to this form.

The form 1 ∞ $\frac{2}{5}$; $\frac{2}{5}$ P ∞ Naumann; 2 0 5 Miller; $O^{\frac{1}{5}}$ Brooke and Levy.

Woolastonite	49° 18′

The form 1 ∞ $\frac{1}{2}$; $\frac{1}{2}$ P ∞ Naumann; 1 0 2 Miller; $O^{\frac{1}{4}}$ Brooke and Levy.

Bragationite	88° 58′	Epidote	89° 27′	Lunnite	76° 34′
Chessylite	64° 25′	Laumonite	68° 40′	Sphene	55° 33′

The form 1 ∞ $\frac{2}{3}$; $\frac{2}{3}$ P ∞ Naumann; 2 0 3 Miller; $O^{\frac{1}{3}}$ Brooke and Levy.

Felspar	81° 54′	Linarite	83° 42′	Woolastonite	40° 7

The form 1 ∞ $\frac{5}{6}$; $\frac{5}{6}$ P ∞ Naumann; 5 0 6 Miller; $O^{\frac{5}{12}}$ Brooke and Levy.

Linarite	78° 59′

The form 1 ∞ $\frac{4}{3}$; $\frac{4}{3}$ P ∞ Naumann; 4 0 3 Miller; $O^{\frac{2}{3}}$ Brooke and Levy.

Felspar	53° 40′	Humite	54° 29′

The form $1 \infty \frac{3}{2}$; $\frac{3}{2} P \infty$ Naumann; 3 0 2 Miller; $O^{\frac{3}{4}}$ Brooke and Levy.

Allanite	34° 30′	Chessylite	33° 24′	Epidote	45° 37′

The form $1 \infty 2$; $2 P \infty$ Naumann; 2 0 1 Miller; O^1 Brooke and Levy.

Bragationite	34° 19′	Heulandite	25° 25′	Placodine	45° 15′
Chessylite	26° 9′	Humite	40° 37′	Realgar	44° 2′
Epidote	34° 21′	Lehmannite	23° 55′	Rhyacolite	35° 38′
Felspar	35° 45′	Linarite	51° 54′	Vivianite	29° 29′
Gaylussite	51° 54′	Mirabilite	32° 26′	Woolastonite	19° 30′

The form $1 \infty 3$; $3 P \infty$ Naumann; 3 0 1 Miller; $O^{\frac{3}{2}}$ Brooke and Levy.

Bragationite	22° 22′	Chessylite	18° 1′	Miargyrite	17° 38′

The form $1 \infty 4$; $4 P \infty$ Naumann; 4 0 1 Miller; O^2 Brooke and Levy.

Humite	21° 38′	Lehmannite	13° 6′

The form $\bar{1} \infty \frac{1}{3}$; $-\frac{1}{3} P \infty$ Naumann; $\bar{3}$ 0 1 Miller; $A^{\frac{1}{6}}$ Brooke and Levy.

Augite	144° 28′	Gypsum	92° 2′

The form $\bar{1} \infty \frac{1}{2}$; $-\frac{1}{2} P \infty$ Naumann; $\bar{2}$ 0 1 Miller; $A^{\frac{1}{4}}$ Brooke and Levy.

Augite	89° 20′	Laumonite	125° 41′	Lunnite	103° 26′
Chessylite	119° 16′				

The form $\bar{1} \infty \frac{2}{3}$; $-\frac{2}{3} P \infty$ Naumann; $\bar{2}$ 0 3 Miller; $A^{\frac{1}{3}}$ Brooke and Levy.

Woolastonite	114° 17′

The form $\bar{1} \infty \frac{4}{3}$; $-\frac{4}{3} P \infty$ Naumann; $\bar{4}$ 0 3 Miller; $A^{\frac{2}{3}}$ Brooke and Levy.

Humite	137° 36′

The form $\bar{1} \infty \frac{3}{2}$; $-\frac{3}{2} P \infty$ Naumann; $\bar{3}$ 0 2 Miller; $A^{\frac{3}{4}}$ Brooke and Levy.

Erythrine	152° 31′	Glauberite	133° 46′	Klinoclase	161° 00′

The form $\bar{1} \infty 2$; $-2 P \infty$ Naumann; $\bar{2}$ 0 1 Miller; A^1 Brooke and Levy.

Amphibole	130° 6′	Glauberite	144° 39′	Mirabilite	155° 41′
Bragationite	157° 20′	Heulandite	155° 5′	Pargasite	130° 6′
Chessylite	154° 44′	Humite	147° 8′	Woolastonite	154° 25′
Felspar	157° 7′				

The form $\bar{1} \infty 3$; $-3 P \infty$ Naumann; $\bar{3}$ 0 1 Miller; $A^{\frac{3}{2}}$ Brooke and Levy.

Lehmannite	160° 41′

The form $\bar{1} \infty 4$; $-4 P \infty$ Naumann; $\bar{4}$ 0 1 Miller; A^2 Brooke and Levy.

Humite	161° 0′	Lehmannite	165° 31′

Oblique Prism on a Rhombic Base of the Second Order.—The oblique rhombic prism of the second order is similar in form to that of the first order, but differs in its position with regard to the axes of the system. The faces of this prism are called *clino-domes*.

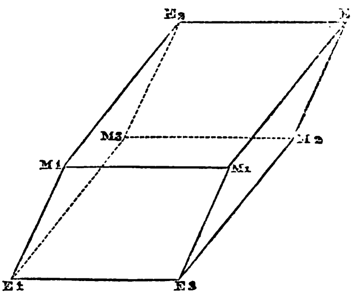


Fig. 336.

Symbols.—Each face passes through one of the extremities of the axes $P_1 P_2$ (Fig. 325) and $H_1 H_2$, and is parallel to the third axis $G_1 G_2$. The symbol which expresses this relation is ∞ 1 1; Naumann's is $(P \infty)$; Miller's 0 1 1; Brooke and Levy's $E^{\frac{1}{2}}$.

To draw this prism prick off the points E_1, E_2, E_3, E_4, and M_1, M_2, M_3, M_4, from Fig. 325, and join them as in Fig. 336.

Position of the Poles of the Oblique Rhombic Prism of the Second Order on the Sphere of Projection.—*The poles of this prism all lie in the zone or meridian $P_1 C P_2$ (Fig. 330);*

two where the circle of north latitude, whose polar distance from c is λ, cuts the meridian $P_1\ CP_2$; and two where the circle of south latitude, whose south polar distance is λ, cuts the same zone.

The formula for determining λ is

$$\tan \lambda = \frac{\tan \gamma \sin \alpha}{\sin (\alpha + \beta)}$$

Faces parallel to the Oblique Rhombic Prism occur in the following Minerals: the angle is λ which determines the latitude of their poles.

Allanite	35° 25′	Humite	35° 17′	Natron	55° 2′
Augite	60° 20′	Hureaulite	44° 0′	Pharmacolite	70° 34′
Bieberite	32° 55′	Klaprothine	30° 42′	Realgar	48° 21′
Bragationite	35° 25′	Laumonite	59° 43′	Sphene	56° 44′
Chessylite	48° 41′	Lehmannite	47° 31′	Spodumene	39° 45′
Epidote	35° 4′	Lunnite	56° 18′	Vivianite	55° 33′
Feuerblende	37° 0′	Melanterite	33° 44′	Wagnerite	54° 25′
Freieslebenite	47° 10′	Miargyrite	19° 9′	Whewellite	37° 25′
Gypsum	67° 47′	Mirabilite	43° 15′	Woolastonite	43° 44′
Heulandite	49° 20′	Monazite	48° 8′		

Sphene has a cleavage parallel to this form.

Oblique Rhombic Prisms derived from those of the Second Order.—By taking CP_1 and CP_2 (Fig. 325) m times the parameter CP (Fig. 326), where m may be any fraction or whole number; and from Fig. 325, so altered, describing an oblique rhombic prism of the second order, a series of prisms, similar in form and position, but differing in magnitude from Fig. 336, may be formed. The faces of these prisms are called *clino-domes*.

Symbols.—Each face of these derived prisms cuts two of the axes $P_1\,P_2$, $H_1\,H_2$, and is parallel to the third $G_1\,G_2$; the symbol which expresses this relation to the axes is $\infty\,1\,m$; Naumann's is $(m\,P\,\infty)$; Miller's $o\,k\,l$; Brooke and Levy's $E^{\frac{m}{2}}$.

Position of the Poles of the derived Oblique Prisms of the Second Order on the Sphere of Projection.—The poles of these prisms all lie in the zone or meridian $P_1\,CP_2$ (Fig. 330); two for each prism where the circle of north latitude, whose polar distance from C is λ, cuts the meridian $P_1\,CP_2$, and two where the circle of south latitude, whose south polar distance is λ, cuts the same zone.

The formula for determining λ is,

$$\tan \lambda = \frac{1}{m}\,\frac{\sin \gamma \sin \alpha}{\sin (\alpha + \beta)}.$$

Faces parallel to the derived Oblique Rhombic Prisms of the Second Order, with the following angles for determining the latitude of their poles, have been observed in nature.

The form $\infty\,1\,\frac{1}{3}$; $(\frac{1}{3}\,P\,\infty)$ Naumann; 0 1 3 Miller; $E^{\frac{1}{6}}$ Brooke and Levy.

Melanterite	63° 28′	Sphene	77° 40′

The form $\infty\,1\,\frac{2}{5}$; $(\frac{2}{5}\,P\,\infty)$ Naumann; 0 2 5 Miller; $E^{\frac{1}{5}}$ Brooke and Levy.

Chessylite	70° 38′

The form $\infty\,1\,\frac{1}{2}$; $(\frac{1}{2}\,P\,\infty)$ Naumann; 0 1 2 Miller; $E^{\frac{1}{4}}$ Brooke and Levy.

Allanite	54° 53′	Euclase	81° 5′	Lehmannite	65° 24′
Bieberite	62° 45′	Feuerblende	56° 26′	Realgar	66° 2′
Bucklandite	54° 33′	Freieslebenite	65° 8′	Wagnerite	70° 19′
Epidote	54° 33′	Klaprothine	49° 45′	Woolastonite	25° 34′

The form $\infty 1 \frac{2}{3}$; $(\frac{2}{3} P \infty)$ Naumann; 0 2 3 Miller; $E^{\frac{1}{2}}$ Brooke and Levy.

Botryogen	70° 30′	Felspar	71° 36′	Woolastonite	55° 8′
Chessylite	59° 37′	Humite	46° 43′		

The form $\infty 1 \frac{3}{2}$; $(\frac{3}{2} P \infty)$ Naumann; 0 3 2 Miller; $E^{\frac{3}{4}}$ Brooke and Levy.

Freieslebenite	35° 43′	Realgar	36° 51′	Wagnerite	42° 59′

The form $\infty 1 2$; $(2 P \infty)$ Naumann; 0 2 1 Miller; E^1 Brooke and Levy.

Amphibole	60° 26′	Gaylussite	35° 15′	Monazite	29° 9′
Augite	41° 27′	Humite	19° 29′	Rhyacolite	45° 16′
Chessylite	29° 37′	Lehmannite	28° 38′	Tincal	24° 51′
Felspar	45° 3′	Mica	24° 45′	Wagnerite	34° 57′
Freieslebenite	28° 21′				

Chessylite has a perfect cleavage parallel to this form.

The form $\infty 1 4$; $(4 P \infty)$ Naumann; 0 4 1 Miller; E^2 Brooke and Levy.

Augite	23° 42′

The form $\infty 1 6$; $(6 P \infty)$ Naumann; 0 6 1 Miller; E^3 Brooke and Levy.

Felspar	18° 28′

Oblique Rhombic Octahedron.—The *oblique rhombic octahedron*, or the *double four-faced oblique pyramid on a rhombic base*, which is also called the *monoclinohedric pyramid*, is a solid bounded by eight scalene triangles. These triangular faces are of two kinds; the faces $P_1 H_1 G_1$ (Fig. 337), $P_1 H_2 G_2$, $P_2 H_1 G_2$, and $P_2 H_2 G_2$, being equal and similar scalene triangles; and the faces $P_1 G_2 H_1$, $P_1 H_2 G_2$, $P_2 H_1 G_1$, and $P_2 H_2 G_1$ being also similar and equal scalene triangles, which are not similar or equal to the former. This solid may be regarded as a combination of two open forms, each consisting only of those faces which are similar and equal to each other.

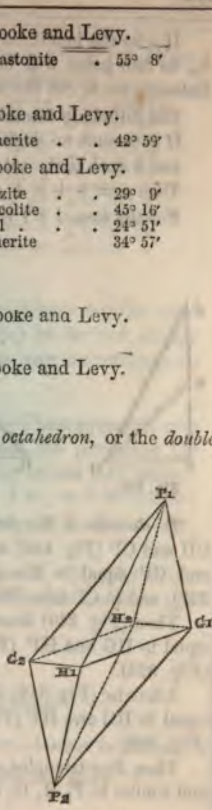


Fig. 337.

To draw the Oblique Rhombic Octahedron.—Prick off from Fig. 325 the points P_1, P_2, H_1, H_2, G_1, G_2, and join these as in Fig. 337.

Axes.—The axes of the oblique system join the points $P_1 P_2$, $H_1 H_2$, and $G_1 G_2$, Fig. 337.

Symbols.—Every face of the pyramid cuts the three axes $P_1 P_2$, $H_1 H_2$, and $G_1 G_2$, at the extremities of the parameters.

1 1 1 may be taken as the symbol for the form whose faces are $P_1 H_1 G_1$, $P_1 H_2 G_1$, $P_2 H_1 G_2$, and $P_2 H_2 G_2$. Naumann's symbol for this form is P; Miller's, 1 1 1; Brooke and Levy's, D. This form is called the *positive hemi-pyramid*.

$\bar{1}$ 1 1 may be taken as the symbol for the form whose faces are $P_1 H_1 G_2$, $P_1 H_2 G_2$, $P_2 H_1 G_1$, and $P_2 H_2 G_1$. Naumann's is — P; Miller's, $\bar{1}$ 1 1; Brooke and Levy's B. This form is called the *negative hemi-pyramid*.

Position of the Poles on the Sphere of Projection.—Two of the poles of each of these forms lie in the same circle of north latitude, and two in the circle of south latitude, whose south polar distance λ is equal to the north polar distance of the former.

Let μ be the longitude of the pole nearest to G_1 (Fig. 330) on the northern hemisphere, reckoning its longitude from G_1, of the form 1 1 1, the four poles of this form will be where the circles of latitude whose north and south polar distances are λ cut the meridians μ and $180 + \mu$.

If μ be the longitude of the nearest pole of $\bar{1}\ 1\ 1$ to G_2, reckoning its longitude from G_1, its four poles will be where the circles of latitude, whose north and south polar distances are λ, cut the meridians μ and $180 + \mu$.

The following formulæ are used for the determination of λ and μ for the form 1 1 1.

If ϕ be such an angle that $\tan \phi = \sin \beta \cos (\alpha + \beta) \operatorname{cosec} \alpha$

and ψ such that $\cot \psi = \sin \phi \operatorname{cosec} (45 + \phi) \sin 45 \tan (\alpha + \beta)$

Then $\mu = \psi + \alpha + \beta - 90^\circ$ and $\tan \lambda = \sin \beta \tan \gamma \sec \psi$

For the form $1\ 1\ \bar{1}$ the formulæ are the same, except that

$$\tan \phi = - \sin \beta \cos (\alpha + \beta) \operatorname{cosec} \alpha.$$

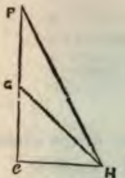


Fig. 338.

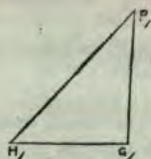


Fig. 339.

Fig. 340.


Fig. 341.

To describe a Net for the Oblique Rhombic Octahedron.—Draw CH and CP (Fig. 338) at right angles to each other; take CH and CP equal to the parameters CH and CP (Figs. 326 and 327), and in CP take CG equal to the parameter CG (Fig. 326). Join HG and HP.

Then (Fig. 339) describe the triangle $H_1\ P_1\ G_1$, having its sides $H_1\ G_1$ and $H_1\ P_1$ equal to HG and HP (Fig. 338), and the side $G_1\ P_1$ equal to a line joining G_1 and P_1 (Fig. 325).

Likewise (Fig. 340) describe the triangle $H_2\ P_1\ G_2$, having its sides $H_2\ G_2$ and $H_2\ P_1$ equal to HG and HP (Fig. 338), and the side $G_2\ P_1$ equal to a line joining G_2 and P_1 (Fig. 325).

Then four triangles equal and similar to $P_1\ H_1\ G_1$ (Fig. 339), and four other equal and similar to $P_1\ H_2\ G_2$ (Fig. 340) arranged as in Fig. 341, will form the required net.

Faces parallel to the Positive Hemipyramid 1 1 1; P *Naumann*; 1 1 1 *Miller*; D *Brooke and Levy, have been observed in the following Minerals.*

Allanite .	. $\lambda = 35^\circ\ 45'$	$\mu = 63^\circ\ 40'$	Laumonite	. $\lambda = 66^\circ\ 43'$	$\mu = 46^\circ\ 37'$
Amphibole	. $\lambda = 77^\circ\ 13'$	$\mu = 50^\circ\ 35'$	Lehmannite	. $\lambda = 59^\circ\ 29'$	$\mu = 39^\circ\ 2'$
Augite .	. $\lambda = 65^\circ\ 42'$	$\mu = 49^\circ\ 50'$	Lunnite .	. $\lambda = 58^\circ\ 54'$	$\mu = 64^\circ\ 28'$
Barytocalcite	. $\lambda = 53^\circ\ 27'$	$\mu = 61^\circ\ 0'$	Melanterite	. $\lambda = 50^\circ\ 46'$	$\mu = 31^\circ\ 53'$
Botryogen .	. $\lambda = 62^\circ\ 41'$	$\mu = 63^\circ\ 5'$	Miargerite	. $\lambda = 26^\circ\ 38'$	$\mu = 40^\circ\ 2'$
Bragationite	. $\lambda = 35^\circ\ 48'$	$\mu = 63^\circ\ 25'$	Mica . .	. $\lambda = 64^\circ\ 46'$	$\mu = 25^\circ\ 19'$
Chessylite .	. $\lambda = 58^\circ\ 3'$	$\mu = 45^\circ\ 4'$	Mirabilite .	. $\lambda = 46^\circ\ 36'$	$\mu = 57^\circ\ 55'$
Epidote .	. $\lambda = 35^\circ\ 16'$	$\mu = 63^\circ\ 43'$	Monazite .	. $\lambda = 59^\circ\ 41'$	$\mu = 39^\circ\ 20'$
Erythrine .	. $\lambda = 59^\circ\ 12'$	$\mu = 55^\circ\ 9'$	Plagionite .	. $\lambda = 71^\circ\ 1'$	$\mu = 54^\circ\ 51'$
Euclase .	. $\lambda = 75^\circ\ 54'$	$\mu = 49^\circ\ 17'$	Realgar .	. $\lambda = 46^\circ\ 59'$	$\mu = 73^\circ\ 33'$
Felspar .	. $\lambda = 63^\circ\ 7'$	$\mu = 65^\circ\ 48'$	Rhyacolite .	. $\lambda = 63^\circ\ 19'$	$\mu = 65^\circ\ 37'$
Freieslebenite	. $\lambda = 64^\circ\ 1'$	$\mu = 31^\circ\ 41'$	Scolezite .	. $\lambda = 72^\circ\ 20'$	$\mu = 69^\circ\ 59'$
Gaylussite .	. $\lambda = 55^\circ\ 15'$	$\mu = 73^\circ\ 50'$	Spodumene	. $\lambda = 45^\circ\ 33'$	$\mu = 49^\circ\ 50'$
Glauberite	. $\lambda = 58^\circ\ 10'$	$\mu = 37^\circ\ 23'$	Tincal .	. $\lambda = 48^\circ\ 20'$	$\mu = 52^\circ\ 33'$
Gypsum .	. $\lambda = 71^\circ\ 51'$	$\mu = 52^\circ\ 16'$	Vauquelinite, not determined.		
Heulandite	. $\lambda = 73^\circ\ 28'$	$\mu = 43^\circ\ 53'$	Vivianite .	. $\lambda = 59^\circ\ 35'$	$\mu = 54^\circ\ 13'$
Humite .	. $\lambda = 37^\circ\ 43'$	$\mu = 64^\circ\ 0'$	Wagnerite	. $\lambda = 56^\circ\ 3'$	$\mu = 63^\circ\ 25'$
Klaprothine	. $\lambda = 50^\circ\ 10'$	$\mu = 29^\circ\ 25'$	Woolastonite	. $\lambda = 59^\circ\ 24'$	$\mu = 32^\circ\ 4'$

Barytocalcite has a perfect cleavage parallel to this form.

Faces parallel to the Negative Hemipyramid $\bar{1}\,1\,1$; $-$ P *Naumann*; $\bar{1}\,1\,1$ *Miller*; B *Brooke and Levy, have been observed in the following Minerals.*

Allanite	$\lambda = 48°\ 18'$	$\mu = 144°\ 56'$	Klaprothine	$\lambda = 49°\ 25'$	$\mu = 149°\ 45'$
Amphibole	$\lambda = 74°\ 14'$	$\mu = 106°\ 2'$	Lehmannite	$\lambda = 53°\ 57'$	$\mu = 128°\ 58'$
Augite	$\lambda = 60°\ 16'$	$\mu = 105°\ 7'$	Mica	$\lambda = 61°\ 27'$	$\mu = 150°\ 27'$
Chessylite	$\lambda = 59°\ 8'$	$\mu = 137°\ 13'$	Mirabilite	$\lambda = 55°\ 21'$	$\mu = 141°\ 42'$
Epidote	$\lambda = 48°\ 5'$	$\mu = 145°\ 17'$	Monazite	$\lambda = 53°\ 18'$	$\mu = 126°\ 8'$
Euclase	$\lambda = 71°\ 55'$	$\mu = 99°\ 59'$	Pargasite	$\lambda = 74°\ 14'$	$\mu = 106°\ 2'$
Felspar	$\lambda = 72°\ 20'$	$\mu = 145°\ 2'$	Plagionite	$\lambda = 67°\ 13'$	$\mu = 94°\ 9'$
Glauberite	$\lambda = 47°\ 41'$	$\mu = 117°\ 6'$	Scolezite	$\lambda = 72°\ 10'$	$\mu = 108°\ 25'$
Gypsum	$\lambda = 69°\ 14'$	$\mu = 113°\ 46'$	Vivianite	$\lambda = 67°\ 7'$	$\mu = 144°\ 20'$
Humite	$\lambda = 42°\ 39'$	$\mu = 131°\ 0'$	Wagnerite	$\lambda = 63°\ 46'$	$\mu = 139°\ 7'$

Augite has a cleavage parallel to this form.

Derived Oblique Rhombic Octahedrons.—From the oblique rhombic octahedron just described, a series of oblique rhombic octahedrons may be derived, similar to it in position, but differing in magnitude. These octahedrons may conveniently be arranged under three classes.

Derived Oblique Octahedron of the First Class.—These pyramids may be drawn by making CP_1 and CP_2 (Fig. 325) equal to m times the parameter CP (Fig. 326), where m may be any whole number or fraction greater or less than unity.

Symbols.—The symbol for the positive hemipyramid is $1\ 1\ m$; m P Naumann; $h\,h\,l$ Miller; D^m Brooke and Levy. For the negative hemipyramid $\bar{1}\ 1\ m$; $-m$ P, Naumann; B^m Brooke and Levy.

Poles.—The poles of the positive hemipyramids lie in the zone $E_1\,CE_2$ (Fig. 330), and those of the negative in the zone $F_1\,CF_2$. To determine λ and μ we have the following formulæ:—

$$\tan\phi = \pm\, m \sin\beta \cos(\alpha + \beta) \operatorname{cosec}\alpha$$
$$\cot\psi = \sin\phi \operatorname{cosec}(45 + \phi) \sin 45 \tan(\alpha + \beta)$$
$$\mu = \psi + \alpha + \beta - 90 \quad \text{and} \quad \tan\lambda = \sin\beta \tan\gamma \sec\psi.$$

Faces parallel to the following Pyramids of the First Class have been observed in Nature.

The form $1\ 1\ \frac{1}{10}$; $\frac{1}{10}$ P Naumann; 1, 1, 10 Miller; D^{10} Brooke and Levy.

Miargyrite	$\lambda = 73°\ 12'$	$\mu = 75°\ 49'$

The form $1\ 1\ \frac{1}{6}$; $\frac{1}{6}$ P Naumann; 1 1 6 Miller; D^6 Brooke and Levy.

Miargyrite	$\lambda = 63°\ 54'$	$\mu = 72°\ 13'$

The form $1\ 1\ \frac{1}{4}$; $\frac{1}{4}$ P Naumann; 1 1 4 Miller; D^4 Brooke and Levy.

Miargyrite	$\lambda = 54°\ 26'$	$\mu = 67°\ 50'$

The form $1\ 1\ \frac{1}{3}$; $\frac{1}{3}$ P Naumann; 1 1 3 Miller; D^3 Brooke and Levy.

Klaprothine	$\lambda = 64°\ 0'$	$\mu = 58°\ 30'$	Sphene	$\lambda = 78°\ 36'$	$\mu = 66°\ 52'$
Miargyrite	$\lambda = 47°\ 9°$	$\mu = 63°\ 37'$			

The form $1\ 1\ \frac{1}{2}$; $\frac{1}{2}$ P Naumann; 1 1 2 Miller; D^2 Brooke and Levy.

Bucklandite	$\lambda = 51°\ 45'$	$\mu = 89°\ 27'$	Mica	$\lambda = 70°\ 4'$	$\mu = 41°\ 7'$
Epidote	$\lambda = 51°\ 45'$	$\mu = 89°\ 27'$	Plagionite	$\lambda = 60°\ 24'$	$\mu = 42°\ 29'$
Felspar	$\lambda = 74°\ 28'$	$\mu = 91°\ 9'$	Sphene	$\lambda = 74°\ 49'$	$\mu = 55°\ 33'$
Freieslebenite	$\lambda = 70°\ 21'$	$\mu = 50°\ 30'$	Spodumene	$\lambda = 58°\ 0'$	$\mu = 76°\ 48'$
Humite	$\lambda = 54°\ 34'$	$\mu = 81°\ 33'$	Tincal	$\lambda = 61°\ 17'$	$\mu = 76°\ 49'$
Klaprothine	$\lambda = 57°\ 45'$	$\mu = 47°\ 55'$	Vivianite	$\lambda = 70°\ 26'$	$\mu = 79°\ 8'$
Miargyrite	$\lambda = 37°\ 49'$	$\mu = 56°\ 11'$	Wagnerite	$\lambda = 69°\ 27'$	$\mu = 85°\ 4'$

Plagionite has a perfect cleavage parallel to this form.

The form $1\ 1\ \frac{2}{3}$; $\frac{2}{3}$ P Naumann; 2 2 3 Miller; $D^{\frac{3}{2}}$ Brooke and Levy.

Chessylite	$\lambda = 63°\ 49'$	$\mu = 56°\ 57'$

The form 1 1 2; 2 P Naumann; 2 2 1 Miller; $D^{\frac{1}{2}}$ Brooke and Levy.

Augite	$\lambda = 55° 35'$	$\mu = 35° 39'$	Humite	$\lambda = 28° 6'$	$\mu = 40° 37'$
Chessylite	$\lambda = 52° 13'$	$\mu = 26° 9'$	Woolastonite	$\lambda = 53° 22'$	$\mu = 19° 30'$
Felspar	$\lambda = 57° 0'$	$\mu = 35° 45'$			

The form 1 1 3; 3 P Naumann; 3 3 1 Miller; $D^{\frac{1}{3}}$ Brooke and Levy.

Euclase	$\lambda = 65° 8'$	$\mu = 27° 51'$

The form 1 1 4; 4 P Naumann; 4 4 1 Miller; $D^{\frac{1}{4}}$ Brooke and Levy.

Lehmannite	$\lambda = 49° 4'$	$\mu = 13° 16'$

The form $\bar{1}\ 1\ \frac{1}{2}$; $-\frac{1}{2}$ P Naumann; $\bar{1}$ 1 2 Miller; B^2 Brooke and Levy.

Bragationite	$\lambda = 60° 37'$	$\mu = 133° 27'$	Vivianite	$\lambda = 74° 41'$	$\mu = 130° 51'$
Miargyrite	$\lambda = 34° 33'$	$\mu = 110° 30'$	Whewellite	$\lambda = 65° 39'$	$\mu = 138° 40'$

The form $\bar{1}\ 1\ \frac{1}{3}$; $-\frac{1}{3}$ P Naumann; $\bar{1}$ 1 3 Miller; B^3 Brooke and Levy.

Glauberite	$\lambda = 71° 22'$	$\mu = 84° 27'$	Klaprothine	$\lambda = 63° 32'$	$\mu = 118° 58'$
Gypsum	$\lambda = 82° 8'$	$\mu = 92° 2'$			

The form $\bar{1}$ 1 2; -2 P Naumann, $\bar{2}$ 2 1 Miller; $B^{\frac{1}{2}}$ Brooke and Levy.

Amphibole	$\lambda = 65° 48'$	$\mu = 130° 6'$	Miargyrite	$\lambda = 19° 22'$	$\mu = 152° 48'$
Augite	$\lambda = 47° 45'$	$\mu = 129° 18'$	Wagnerite	$\lambda = 50° 51'$	$\mu = 153° 14'$
Chessylite	$\lambda = 53° 7'$	$\mu = 154° 44'$	Woolastonite	$\lambda = 46° 7'$	$\mu = 154° 25'$
Humite	$\lambda = 32° 38'$	$\mu = 147° 8'$			

The form $\bar{1}$ 1 3; -3 P Naumann; $\bar{3}$ 3 1 Miller; $B^{\frac{1}{3}}$ Brooke and Levy.

Augite	$\lambda = 44° 4'$	$\mu = 143° 17'$	Glauberite	$\lambda = 71° 22'$	$\mu = 84° 27'$

Derived Oblique Octahedron of the Second Class.—This octahedron may be drawn and its net described, by making CP_1 and CP_2 (Fig. 325) m times the parameter CP (Fig. 326); where m may be any whole number or fraction equal to, greater, or less than unity: and CH_1 and CH_2 (Fig. 325) n times the parameter CH (Fig. 327), where n may be any whole number or fraction greater than unity.

Symbols.—The symbol for the positive hemipyramid of this octahedron is $1\,n\,m$; m P n Naumann; $h\,k\,l$ Miller; $D^1\,D^{\frac{n+1}{n-1}}\,H^{\frac{m(n+1)}{2n}}$ Brooke and Levy: for the negative hemipyramid $\bar{1}\,n\,m$; $-m$ P n Naumann; $\bar{h}\,k\,l$ Miller; $B^1\,B^{\frac{n+1}{n-1}}\,H^{\frac{m(n+1)}{2n}}$ Brooke and Levy.

Poles.—To determine the position of the poles we have the following formulæ:—

$$\tan\phi = \pm\, m \sin\beta \cos(\alpha + \beta) \operatorname{cosec}\alpha$$

$$\cot\psi = \sin\phi \operatorname{cosec}(45 + \phi) \sin 45 \tan(\alpha + \beta)$$

$$\mu = \psi + \alpha + \beta - \psi \text{ and } \tan\lambda = n \sin\beta \tan\gamma \sec\psi.$$

The positive or negative sign being used for $\tan\phi$, according as the hemipyramid is positive or negative.

Faces parallel to the following Pyramids of the Second Class have been observed in nature.

The form $1\ 2\ \frac{1}{2}$; $\frac{1}{2}$ P 2 Naumann; 2 1 4 Miller; $D^1\,D^3\,H^{\frac{3}{8}}$ Brooke and Levy.

Sphene	$\lambda = 82° 16'$	$\mu = 55° 33'$

The form 1 2 1; P 2 Naumann; 2 1 2 Miller; $D^1\,D^3\,H^{\frac{3}{4}}$ Brooke and Levy.

Klaprothine	$\lambda = 67° 22'$	$\mu = 29° 25'$	Spodumene	$\lambda = 45° 33'$	$\mu = 49° 50'$
Miargyrite	$\lambda = 45° 5'$	$\mu = 40° 2'$	Wagnerite	$\lambda = 71° 24'$	$\mu = 65° 25'$
Realgar	$\lambda = 64° 59'$	$\mu = 73° 33'$			

Realgar has a cleavage parallel to this form.

The form 1 2 $\frac{4}{3}$; $\frac{4}{3}$ P 2 Naumann; 4 2 3 Miller; $D^1 D^3 H^1$ Brooke and Levy.
Humite . . $\lambda = 52° \ 2'$ $\mu = 54° \ 29'$

The form 1 2 2; 2 P 2 Naumann; 2 1 1 Miller; $D^1 D^3 H^{\frac{3}{2}}$ Brooke and Levy.
Chessylite . $\lambda = 68° \ 49'$ $\mu = 26° \ 9'$
Epidote . . $\lambda = 48° \ 21'$ $\mu = 34° \ 21'$
Humite . . $\lambda = 45° \ 53'$ $\mu = 40° \ 37'$
Miargyrite . $\lambda = 38° \ 36'$ $\mu = 25° \ 8'$
Mirabilite . $\lambda = 59° \ 6'$ $\mu = 32° \ 26'$

The form 1 2 4; 4 P 2 Naumann; 4 2 1 Miller; $D^1 D^3 H^3$ or ${}_3A$ Brooke and Levy.
Miargyrite . $\lambda = 35° \ 34'$ $\mu = 13° \ 4'$ | Realgar . . $\lambda = 54° \ 15'$ $\mu = 26° \ 7'$

The form 1 $\frac{7}{3}$ 7; 7 P $\frac{7}{3}$ Naumann; 7 3 1 Miller; $D^1 D^{\frac{5}{2}} H^5$ Brooke and Levy.
Miargyrite . $\lambda = 88° \ 56'$ $\mu = 7° \ 39'$

The form 1 3 $\frac{3}{4}$; $\frac{3}{4}$ P 3 Naumann; 3 1 4 Miller; $D^1 D^2 H^{\frac{1}{2}}$ Brooke and Levy.
Wagnerite . $\lambda = 79° \ 35'$ $\mu = 73° \ 37'$

The form 1 3 $\frac{3}{2}$; $\frac{3}{2}$ P 3 Naumann; 3 1 2 Miller; $D^1 D^2 H^1$ Brooke and Levy.
Freieslebenite $\lambda = 79° \ 55'$ $\mu = 22° \ 34'$

The form 1 3 2; 2 P 3 Naumann; 6 2 3 Miller; $D^1 D^2 H^{\frac{4}{3}}$ Brooke and Levy.
Humite . . $\lambda = 58° \ 1'$ $\mu = 40° \ 37'$

The form 1 3 3; 3 P 3 Naumann; 3 1 1 Miller; $D^1 D^2 H^2$ or ${}_2A$ Brooke and Levy.
Miargyrite . $\lambda = 47° \ 59'$ $\mu = 17° \ 38'$

The form 1 4 1; P 4 Naumann; 4 1 4 Miller; $D^1 D^{\frac{5}{3}} H^{\frac{5}{8}}$ Brooke and Levy.
Freieslebenite . $\lambda = 83° \ 3'$ $\mu = 31° \ 4'$

The form 1 4 2; 2 P 4 Naumann; 4 1 2 Miller; $D^1 D^{\frac{5}{3}} H^{\frac{6}{4}}$ Brooke and Levy.
Realgar . . $\lambda = 71° \ 19'$ $\mu = 44° \ 2'$

The form 1 4 4; 4 P 4 Naumann; 4 1 1 Miller; $D^1 D^{\frac{5}{3}} H^{\frac{6}{2}}$ Brooke and Levy.
Chessylite . $\lambda = 78° \ 16'$ $\mu = 14° \ 10'$

The form 1 5 5; 5 P 5 Naumann; 5 1 1 Miller; $D^1 D^{\frac{3}{2}} H^3$ Brooke and Levy.
Miargyrite . $\lambda = 60° \ 23'$ $\mu = 10° \ 34'$

The form 1 6 3; 3 P 6 Naumann; 6 1 2 Miller; $D^1 D^{\frac{7}{6}} H^{\frac{7}{4}}$ Brooke and Levy.
Realgar . . $\lambda = 76° \ 34'$ $\mu = 29° \ 25'$

The form $\bar{1}$ $\frac{3}{2}$ 1; $-$P $\frac{3}{2}$ Naumann; $\bar{3}$ 2 1 Miller; $B^1 B^5 H^{\frac{2}{3}}$ Brooke and Levy.
Pharmacolite . $\lambda = 69° \ 38'$ $\mu = 148° \ 42'$ | Euclase . . $\lambda = 67° \ 10'$ $\mu = 99° \ 59'$

The form $\bar{1}$ 2 1; $-$ P 2 Naumann; $\bar{2}$ 1 2 Miller; $B^1 B^3 H^{\frac{3}{4}}$ Brooke and Levy.
Realgar . . $\lambda = 72° \ 33'$ $\mu = 139° \ 46'$

The form $\bar{1}$ 2 2; $-$ 2 P 2 Naumann; $\bar{2}$ 1 1 Miller; $B^1 B^3 H^{\frac{3}{2}}$ Brooke and Levy.
Bragationite . $\lambda = 59° \ 8'$ $\mu = 157° \ 20'$ | Lehmannite . $\lambda = 65° \ 49'$ $\mu = 128° \ 58'$

The form $\bar{1}$ 2 4; $-$ 4 P 2 Naumann; $\bar{4}$ 2 1 Miller; $B^1 B^3 H^3$ or A_3 Brooke and Levy.
Humite . . $\lambda = 46° \ 52'$ $\mu = 161° \ 0'$

The form $\bar{1}$ 3 1; $-$ P 3 Naumann; $\bar{3}$ 1 3 Miller; $B^1 B^2 H^{\frac{3}{3}}$ Brooke and Levy.
Gypsum . . $\lambda = 67° \ 30'$ $\mu = 113° \ 46'$ | Miargyrite . $\lambda = 53° \ 10'$ $\mu = 131° \ 46'$

The form $\bar{1}$ 3 3; $-$ 3 P 3 Naumann; $\bar{3}$ 1 1 Miller; $B^1 B^2 H^2$ or A_2 Brooke and Levy.
Amphibole . $\lambda = 49° \ 52'$ $\mu = 106° \ 2'$
Euclase . . $\lambda = 78° \ 6'$ $\mu = 140° \ 20'$
Glauberite . $\lambda = 68° \ 4'$ $\mu = 155° \ 25'$

The form $\bar{1}\,6\,1$; $-$P 6 Naumann ; $\bar{6}\,1\,6$ Miller ; $B^1\,B^{\frac{7}{5}}\,H^{\frac{7}{12}}$ Brooke and Levy.
Miargyrite . $\lambda = 70°\,30'$ $\mu = 131°\,46'$

Derived Oblique Octahedron of the Third Class.—This octahedron may be drawn and its net described, by making CP_1 and CP_1 (Fig. 325) m times the parameter CP (Fig. 326); where m may be any whole number or fraction, equal to, greater, or less than unity; and CG_1, CG_2 (Fig. 325) equal to n times the parameter CG (Fig. 326), where n may be any whole number, or fraction greater than unity.

Symbols.—The symbol for the positive hemipyramid of this octahedron is $n\,1\,m$; (m P n) Naumann ; $k\;h\;l$ Miller ; $D^1\,D^{\frac{n+1}{n-1}}\,G^{\frac{m(n+1)}{2n}}$ Brooke and Levy. For the negative hemipyramid $\bar{n}\,1\,m$; — (m P n) Naumann ; $\bar{k}\;h\;l$ Miller ; $B^1\,B^{\frac{n+1}{n-1}}\,G^{\frac{m(n+1)}{2n}}$ Brooke and Levy.

Poles.—To determine the position of the poles we have the following formulæ :—

$$\tan\phi = \pm\frac{m}{n}\sin\beta\cos(\alpha+\beta)\operatorname{cosec}\alpha$$

$$\cot\psi = \sin\phi\operatorname{cosec}(45+\phi)\sin 45\tan(\alpha+\beta)$$

$$\mu = \psi + \alpha + \beta - \psi \quad \text{and} \quad \tan\lambda = \frac{1}{n}\sin\beta\tan\gamma\sec\psi$$

The positive or negative sign being used for $\tan\phi$ according as the hemipyramid is positive or negative.

Faces parallel to the following Pyramids of the Third Class have been observed in nature.

The form $\frac{3}{2}\,1\,\frac{3}{2}$; ($\frac{3}{2}$ P $\frac{3}{2}$) Naumann ; 2 3 2 Miller ; $D^1\,D^5\,G^{\frac{5}{4}}$ Brooke and Levy.
Realgar . . $\lambda = 35°\,33'$ $\mu = 73°\,33'$

The form $2\,1\,\frac{2}{5}$; ($\frac{2}{5}$ P 2) Naumann ; 1 2 5, Miller ; $D^1\,D^3\,G^{\frac{3}{10}}$ Brooke and Levy.
Chessylite . . $\lambda = 71°\,35'$ $\mu = 80°\,32'$

The form $2\,1\,\frac{2}{3}$; ($\frac{2}{3}$ P 2) Naumann ; 1 2 3 Miller ; $D^1\,D^3\,G^{\frac{1}{2}}$ Brooke and Levy.
Sphene . . . $\lambda = 68°\,2'$ $\mu = 66°\,52'$

The form $2\,1\,\frac{4}{5}$; ($\frac{4}{5}$ P 2) Naumann ; 2 4 5 Miller ; $D^1\,D^3\,G^{\frac{3}{5}}$ Brooke and Levy.
Chessylite . . $\lambda = 56°\,35'$ $\mu = 69°\,29'$

The form 2 1 1 ; (P 2) Naumann ; 1 2 2 Miller ; $D^1\,D^3\,G^{\frac{3}{4}}$ Brooke and Levy.
Epidote . . $\lambda = 32°\,23'$ $\mu = 89°\,27'$ | Wagnerite . . $\lambda = 53°\,2'$ $\mu = 85°\,4'$

The form $2\,1\,\frac{4}{3}$; ($\frac{4}{3}$ P 2) Naumann ; 2 4 3 Miller ; $D^1\,D^3\,G^1$ Brooke and Levy.
Chessylite . . $\lambda = 45°\,29'$ $\mu = 56°\,57'$

The form 2 1 2 ; (2 P 2) Naumann ; 1 2 1 Miller ; $D^1\,D^3\,G^{\frac{3}{2}}$ Brooke and Levy.
Barytocalcite . $\lambda = 34°\,0'$ $\mu = 61°\,0'$ | Monazite . . $\lambda = 40°\,32'$ $\mu = 39°\,20'$
Freieslebenite . $\lambda = 76°\,18'$ $\mu = 31°\,41'$ | Natron . $\lambda = 39°\,50'$ $\mu = 58°\,52'$

The form 2 1 4 ; (4 P 2) Naumann ; 2 4 1 Miller ; $D^1\,D^3\,G^3$ or E_3 Brooke and Levy.
Chessylite . . $\lambda = 32°\,50'$ $\mu = 26°\,9'$ | Felspar . . $\lambda' = 37°\,35'$ $\mu = 35°\,45'$

The form $3\,1\,\frac{3}{4}$; ($\frac{3}{4}$ P 3) Naumann ; 1 3 4 Miller ; $D^1\,D^2\,G^{\frac{1}{2}}$ Brooke and Levy.
Chessylite . . $\lambda = 57°\,12'$ $\mu = 77°\,41'$

The form $3\,1\,\frac{3}{2}$; ($\frac{3}{2}$ P 3) Naumann ; 1 3 2 Miller ; $D^1\,D^2\,G^1$ Brooke and Levy.
Wheweilite . $\lambda = 28°\,41'$ $\mu = 62°\,49'$

The form 3 1 3; (3 P 3) Naumann; 1 3 1 Miller; $D^1 D^2 G^2$ or E_2 Brooke and Levy.

Amphibole	$\lambda = 55° 46'$	$\mu = 50° 35'$	Felspar	$\lambda = 33° 20'$	$\mu = 65° 48'$
Augite	$\lambda = 36° 26'$	$\mu = 49° 50'$	Gypsum	$\lambda = 45° 39'$	$\mu = 52° 16'$
Euclase	$\lambda = 53° 0'$	$\mu = 49° 17'$			

The form 4 1 4; (4 P 4) Naumann; 1 4 1 Miller; $D^1 D^{\frac{5}{3}} G^{\frac{5}{2}}$ Brooke and Levy.

Sphene . . $\lambda = 33° 52'$ $\mu = 34° 27'$

The form 5 1 $\frac{5}{2}$; ($\frac{5}{2}$ P 5) Naumann; 1 5 2 Miller; $D^1 D^{\frac{3}{2}} G^{\frac{3}{2}}$ or $E_{\frac{3}{2}}$ Brooke and Levy.

Augite . . $\lambda = 37° 49'$ $\mu = 60° 29'$

The form 6 1 2; (2 P 6) Naumann; 1 6 3 Miller; $D^1 D^{\frac{7}{5}} G^{\frac{7}{6}}$ Brooke and Levy.

Sphene . . $\lambda = 39° 34'$ $\mu = 66° 52'$

The form $\bar{\frac{4}{3}}$ 1 4; — (4 P $\frac{4}{3}$) Naumann; $\bar{3}$ 4 1 Miller; $B^1 B^7 G^{\frac{7}{2}}$ Brooke and Levy.

Euclase . . $\lambda = 49° 52'$ $\mu = 140° 20'$

The form $\bar{2}$ 1 1; — (P 2) Naumann; $\bar{1}$ 2 2 Miller; $B^1 B^3 G^{\frac{3}{4}}$ Brooke and Levy.

Wagnerite	$\lambda = 59° 30'$	$\mu = 126° 32'$	Lunnite	$\lambda = 56° 58'$	$\mu = 103° 26'$

The form $\bar{2}$ 1 $\frac{4}{3}$; — ($\frac{4}{3}$ P 2) Naumann; $\bar{2}$ 4 3 Miller; $B^1 B^3 G^1$ Brooke and Levy.

Chessylite . $\lambda = 46° 36'$ $\mu = 126° 12'$

The form $\bar{2}$ 1 2; — (2 P 2) Naumann; $\bar{1}$ 2 1 Miller; $B^1 B^3 G^{\frac{3}{2}}$ Brooke and Levy.

Chessylite	$\lambda = 39° 55'$	$\mu = 137° 13'$	Gypsum	$\lambda = 52° 50'$	$\lambda = 113° 46'$
Euclase	$\lambda = 56° 52'$	$\mu = 99° 59'$	Sphene	$\lambda = 55° 27'$	$\lambda = 148° 28'$

The form $\bar{2}$ 1 $\frac{8}{3}$; — ($\frac{8}{3}$ P 2) Naumann; $\bar{4}$ 8 3 Miller; $B^1 B^3 G^2$ Brooke and Levy.

Augite . . $\lambda = 34° 51'$ $\mu = 114° 31'$

The form $\bar{2}$ 1 4; — (4 P 2) Naumann; $\bar{2}$ 4 1 Miller; $B^1 B^3 G^3$ or ${}_3E$ Brooke and Levy.

Felspar . . $\lambda = 49° 10'$ $\mu = 157° 7'$

The form $\bar{3}$ 1 3; — (3 P 3) Naumann; $\bar{1}$ 3 1 Miller; $B^1 B^2 G^2$ or ${}_2E$ Brooke and Levy.

Amphibole	$\lambda = 49° 45'$	$\mu = 106° 2'$	Mica	$\lambda = 31° 30'$	$\mu = 150° 27'$
Gypsum	$\lambda = 41° 19'$	$\mu = 113° 46'$			

The combinations of this system are so like those of the Prismatic, that we need not give any examples of them.

SIXTH SYSTEM—ANORTHIC, OR DOUBLY OBLIQUE.

This system is called the *anorthic* from the want of symmetry of its forms; and the *doubly oblique* because its forms may be derived from the *doubly oblique prism*, and *doubly oblique octahedron*. It has also been called the *Triclinohedric*, *Anorthotype*, *Tetarto-prismatic*, *Tetarto-rhombic*, and the *One-and-one-membered* system.

To this system all forms may be referred which cannot be placed under any of the preceding systems.

Only two forms belong to the *anorthic system*: the *doubly oblique prism*, and the *doubly oblique octahedron* or *pyramid*.

Alphabetical list of Minerals belonging to the Anorthic or Doubly Oblique System, with the Angular Elements from which their typical forms and axes may be derived. Blanks are left in the cases where the Angular Elements have not been determined.

	α ° ′	β ° ′	γ ° ′	A ° ′	B ° ′	C ° ′	δ ° ′	ϵ ° ′
Albite (cleavelandite: Tetarto-prismatic felspar)	94 46	63 26	93 8	93 36	63 36	91 18	58 26	41 35
Axinite	91 49	82 2	102 36	90 5	82 14	102 30	52 0	51 21
Babingtonite	93 36	86 47	112 39	92 34	88 0	112 30	39 18	23 49
Blue vitriol (sulphate of copper)	73 12	67 8	82 56	70 22	65 4	100 41	28 4	27 16
Christianite (anorthite)	93 11	63 46	88 41	94 12	63 38	86 58	57 31	40 55
Kyanite (disthene)	—	—	—	—	—	—	—	—
Labradorite (Labrador felspar)	94 46	63 26	93 8	93 36	63 36	91 18	58 26	41 35
Latrobite	—	—	—	—	—	—	—	—
Leucophane	—	—	—	—	—	—	—	—
Oligoclase	94 46	63 26	93 8	93 36	63 36	91 18	58 26	41 35
Sassoline (native boracic acid)	92 32	104 18	89 42	92 32	104 18	90 20	29 59	27 51

Parameters and Axes.—In the anorthic system the three parameters are unequal, and no two axes are inclined to each other at right angles. By means of the angular elements α, β, A, δ and ϵ we may determine the lengths of the parameters and the inclination of the axes.

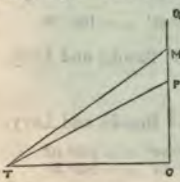


Fig. 342.

To determine the Lengths of the Parameters.—Take a straight line OT (Fig. 342) of any convenient length to represent one of the parameters; this will be the arbitrary unit of the system. Through one of its extremities O, draw OQ perpendicular to OT; through T draw TM, making an angle δ; and TP making an angle ϵ with OT; let TM and TP cut OQ in M and P.

Then OM and OP will represent the lengths of the other two parameters.

To represent the Inclination of the Axes in Perspective.—Draw a straight line XOX′ (Fig. 343), and through O a point in it the line OZ perpendicular to XX′, and the line OY making with OX′ an angle of about 30° with OX′. Along OX take OT_1 equal OT (Fig. 342).

Fig. 343.

Then (Fig. 344) draw a line ABC, and through B a point in it draw BD making the angle γ with AB, take BD equal to OM (Fig. 342), and through D draw DF perpendicular to AC. In OY (Fig. 343) take OD equal to half of DF (Fig. 344), and through D (Fig. 343) draw DM_1 parallel to OX and equal to BF (Fig. 344). Join OM_1 and produce it to OY′.

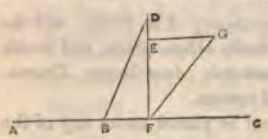


Fig. 344.

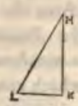


Fig. 345.

Now (Fig. 344) draw FG making the angle β with FC, take FG equal to OP (Fig. 342), and through G draw GE perpendicular to DF.

Draw HK and KL (Fig. 345) at right angles to each other, take KH equal to FE (Fig. 344); through H draw HL, making the angle 90° — A with HK and meeting KL in L.

In OY (Fig. 343) take OE equal to half of LK (Fig. 345), through E draw EF parallel to OZ and equal to HK (Fig. 345).

Through F draw FP_1 parallel to OX and equal to EG (Fig. 336); join OP_1 and produce it to any point Z′.

Then OX, OY′ and OZ′ will represent the direction of the axes for any substance whose angular elements α, β and A are given (page 458), and OT, OM, and OP will represent the magnitude of its parameters, depending upon the angles δ and ϵ.

Doubly Oblique Prism—First Order.—The doubly oblique prism is a solid bounded by six faces, which are all oblique parallelograms, and equal to each other

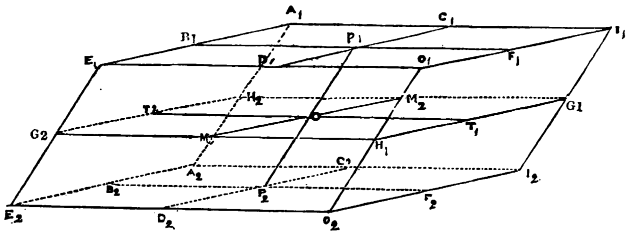


Fig. 346.

only in pairs. The face $A_1 E_1 O_1 I_1$ (Fig. 346) being equal and parallel to the face $A_2 E_2 O_2 I_2$; the face $O_1 I_1 I_2 O_2$ equal and parallel to $E_1 A_1 A_2 E_2$; and the face $A_1 I_1 I_2 A_2$ equal and parallel to $E_1 O_1 O_2 E_2$.

This prism, like the oblique prism, is now generally regarded as a combination of three open forms, each consisting of a pair of parallel faces.

Symbols.—The *basal pinacoids* $O_1 I_1 A_1 E_1$, $O_2 I_2 A_2 E_2$ cut the axis $P_1 P_2$ at the extremities of the parameters OP_1, OP_2, and are parallel to the axes $M_1 M_2$, $T_1 T_2$; the symbol which expresses this relation is $\infty\ \infty\ 1$; Naumann's symbol is OP; Miller's 0 0 1; Brooke and Levy's P.

The *macro-pinacoids* $O_1 E_1 E_2 O_2$ and $A_1 I_1 I_2 A_2$ cut the axis $M_1 M_2$ at the extremities of the parameters OM_1, OM_2, and are parallel to the axes $P_1 P_2$ and $T_1 T_2$. Their symbol is $\infty\ 1\ \infty$; $\infty \bar{P} \infty$ Naumann; 0 1 0 Miller; and M Brooke and Levy.

The *brachy-pinacoids* $O_1 I_1 I_2 O_2$ and $E_1 A_1 A_2 E_2$ cut the axis $T_1 T_2$ at the extremities of the parameters OT_1, OT_2, and are parallel to the axes $P_1 P_2$, $M_1 M_2$. Their symbol is $1\ \infty\ \infty$; $\infty \breve{P} \infty$ Naumann; 1 0 0 Miller; T Brooke and Levy.

To draw the Doubly Oblique Prism, First Order.—Prick off from Fig. 343 the points O, P_1, M_1 and T_1. Join M_1 O and produce it to M_2, making OM_2 equal OM_1.

Join P_1 O and produce to P_2, making OP_2 equal to OP_1. And join T_1 O, produce it to T_2, making OT_2 equal to OT_1.

Through M_1 and M_2 draw $H_1 G_2$ and $G_1 H_2$ parallel to $T_1 T_2$, making $M_1 H_1$, $M_1 G_2$, $M_2 G_1$, and $M_2 H_2$ each equal to OT_1.

Join $H_1 G_1$ and $H_2 G_2$. Through H_1, G_1, H_2, and G_2 draw $O_1 O_2$, $I_1 I_2$, $A_1 A_2$ and $E_1 E_2$ parallel to $P_1 P_2$.

Make $O_1 H_1$, $O_2 H_1$, $G_1 I_1$, $G_1 I_2$, $H_2 A_1$, $H_2 A_2$, $G_2 E_1$ and $G_2 E_2$ each equal to OP_1.

Join $O_1 I_1$, $I_1 A_1$, $A_1 E_1$, $E_1 O_1$, $O_2 I_2$, $I_2 A_2$, $A_2 E_2$ and $O_2 E_2$.

To describe a Net for the Doubly Oblique Prism.—Draw CD (Fig. 347) equal twice OT (Fig. 342) and DB, making the angle γ with CD, and equal to twice OM (Fig. 342).

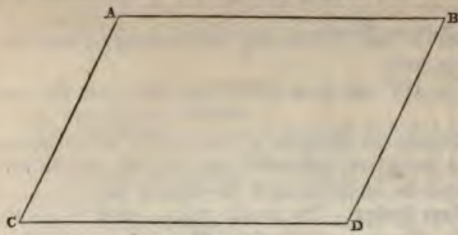


Fig. 347.

Through C draw CA parallel to BD, and through B, BA parallel to CD meeting in A.

Draw GH (Fig. 348) equal twice OT (Fig. 342) and GE, making the angle β with GH, and equal to twice OP (Fig. 342).

Through E draw EF parallel to GH and through H, HF parallel to EG meeting in F.

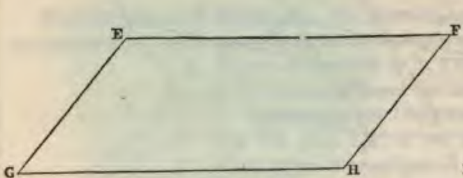


Fig. 348.

Fig. 349.

Also draw MN (Fig. 349) equal to twice OM (Fig. 342) and MK, making the angle α with MN and equal to twice OP (Fig. 342).

Through K draw KL parallel to MN and through N, NL parallel to MK meeting in L.

Then arrange six parallelograms, equal and similar in pairs to the three parallelograms (Figs. 347, 348, and 349), as in Fig. 350, and the net will be described.


Fig. 350.

Crystals of the following minerals have Faces parallel to the Basal Pinacoids $\infty \infty 1$; O P *Naumann*; 0 0 1 *Miller*; P *Brooke and Levy*. *The north and south poles of the Sphere of Projection may be considered the poles of the two faces of the Basal Pinacoids.*

Albite	Babingtonite	Christianite	Oligoclase
Axinite	Blue Vitriol	Labradorite	Sassoline

The following present Cleavages parallel to this form.

Albite	*Babingtonite*	*Labradorite*	*Sassoline*
Axinite	*Christianite*	*Oligoclase*	

Crystals of the following minerals have Faces parallel to the Macro-pinacoids $\infty\ 1\ \infty$; $\infty\ \bar{P}\ \infty$ *Naumann;* 0 1 0 *Miller*; M *Brooke and Levy. The angles will determine the position of one of the poles.*

Albite	North	Polar distance	86° 24′	Longitude	West	90° 0′
Axinite	North	,, ,,	89° 55′	,,	,,	90° 0′
Babingtonite	North	,, ,,	87° 26′	,,	,,	90° 0′
Blue Vitriol	South	,, ,,	70° 22′	,,	,,	90° 0′
Christianite	North	,, ,,	85° 48′	,,	,,	90° 0′
Labradorite	North	,, ,,	86° 24′	,,	,,	90° 0′
Oligoclase	North	,, ,,	86° 24′	,,	,,	90° 0′

The following present Cleavages parallel to this form.

Albite Axinite *Christianite* Labradorite Oligoclase.

Crystals of the following minerals have Faces parallel to the Brachy-pinacoids $1\ \infty\ \infty$;

$\infty\ \breve{P}\ \infty$ *Naumann;* 1 0 0 *Miller;* T *Brooke and Levy.*

Axinite	South	Polar distance	82° 14′	Longitude	West	12° 36′
Babingtonite	South	,, ,,	88° 0′	,,	West	22° 39′
Blue Vitriol	South	,, ,,	65° 4′	,,	East	7° 4′
Sassoline	North	,, ,,	75° 42′	,,	East	0° 18′

Axinite and Babingtonite have imperfect cleavages parallel to this form.

Doubly Oblique Rhombic Prism, Second Order.—If we bisect the edges $O_1 I_1$ (Fig. 346) $O_2 I_2$ in F_1 and F_2, the edges $A_1 E_1$ and $A_2 E_2$ in B_1 and B_2; the edges $O_1 E_1$, $O_2 E_2$ in D_1 and D_2; and the edges $A_1 I_1$, $A_2 I_2$ in C_1 and C_2: and then prick off the points B_1, D_1, F_1, C_1, B_2, D_2, F_2, C_2, and join them as in Fig. 350, we shall derive from the doubly oblique prism (Fig. 346) another doubly oblique prism, similar in form, but differing in position and magnitude with respect to the oblique axes of the anorthic system.

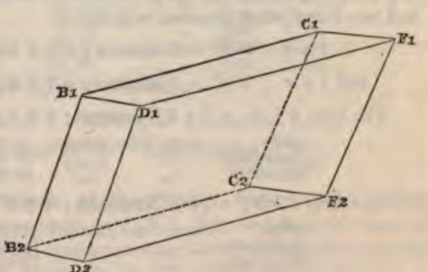


Fig. 351.

This prism is generally considered as the combination of three forms, each consisting of a pair of parallel faces.

$B_1\ D_1\ C_1\ F_1$ and $B_2\ D_2\ C_2\ F_2$ are regarded as faces of the basal pinacoid.

Symbols.—The form whose faces are $D_1\ F_1\ F_2\ D_2$ and $B_1\ C_1\ C_2\ B_2$ cuts each of the axes $M_1\ M_2$, $T_1\ T_2$ at the extremities of their parameters, and is parallel to the third axis $P_1\ P_2$. Its symbol is $1\ 1\ \infty$; ∞ P¦ Naumann; 1 1 0 Miller; H[1] Brooke and Levy.

The form whose faces are $B_1\ D_1\ B_2\ D_2$ and $C_1\ F_1\ C_2\ F_2$ cuts each of the axes $M_1\ M_2$, $T_1\ T_2$ (Fig. 346) at the extremities of their parameters, and is parallel to the third axis $P_1\ P_2$. Its symbol is $\bar{1}\ 1\ \infty$; ∞ ¦P Naumann; $\bar{1}$ 1 0 Miller; G Brooke and Levy.

The form 1 1 ∞ ; ∞ P¦ Naumann; 1 1 0 Miller; H[1] Brooke and Levy, occurs

Albite	South	Polar distance	69° 9′	Longitude	West	33° 50′
Axinite	South	,, ,,	84° 29′	,,	West	45° 41′
Blue Vitriol	South	,, ,,	62° 25′	,,	West	60° 29′
Christianite	South	,, ,,	69° 3′	,,	West	31° 33′
Labradorite	South	,, ,,	69° 9′	,,	West	33° 50′
Oligoclase	South	,, ,,	69° 9′	,,	West	33° 50′
Sassoline	North	,, ,,	80° 33′	,,	West	59° 6′

Blue Vitriol, Labradorite, and Oligoclase have imperfect cleavages parallel to t form.

The form $\bar{1}$ 1 ∞; ∞¦P Naumann; $\bar{1}$ 1 0 Miller; G[1] Brooke and Levy.

Albite	North	Polar distance	64° 55′	Longitude	West	150° 44′
Axinite	North	,, ,,	83° 33′	,,	West	150° 1′
Babingtonite	North	,, ,,	85° 54′	,,	West	137° 49′
Blue Vitriol	South	,, ,,	83° 8′	,,	West	116° 24′
Christianite	North	,, ,,	65° 38′	,,	West	146° 35′
Labradorite	North	,, ,,	64° 55′	,,	West	150° 44′
Oligoclase	North	,, ,,	64° 55′	,,	West	150° 44′
Sassoline	South	,, ,,	84° 57′	,,	West	119° 55′

Albite and Blue Vitriol have cleavages parallel to this form.

Doubly Oblique Prisms derived from that of the Second Order.— making OT_1 and OT_2 in Fig. 346 n times greater than the parameter OT (Fig. 34 where n is any whole number or fraction greater than unity, we may from Fig. 3 so altered, derive another prism of the second order composed of the basal pinaco and two forms whose symbols will be

n 1 ∞ ; ∞ $\bar{P}$¦ n Naumann; 1 n 0 Miller; H^n Brooke and Levy.

and $\bar{n}$ 1 ∞ ; ∞ ¦$\bar{P}$ n Naumann; $\bar{1}$ n 0 Miller; G^n Brooke and Levy.

By making OM_1 and OM_2 (Fig. 346) n times greater than the parameter C (Fig. 342), where n is any whole number or fraction greater than unity, we may fr Fig. 346, so altered, derive a prism of the second order composed of the basal pinaco and two forms whose symbols will be

1 n ∞ ; ∞ $\breve{P}$¦ n Naumann; n 1 0 Miller; $H^{\frac{1}{n}}$ Brooke and Levy.

and $\bar{1}$ n ∞ ; ∞ ¦P n Naumann; $\bar{n}$ 1 0 Miller; $G^{\frac{1}{n}}$ Brooke and Levy.

The form 3 1 0; ∞ $\bar{P}$¦ 3 Naumann; 1 3 0 Miller; H[3] Brooke and Levy.

Albite	South Polar distance	79° 56′	Longitude West	62° 15′
Christianite	,, ,,	80° 33′	,, ,,	63° 5′
Oligoclase	,, ,,	79° 56′	,, ,,	62° 15′

The form $\bar{3}$ 1 0; ∞ ¦P 3 Naumann; $\bar{1}$ 3 0 Miller; G[3] Brooke and Levy.

Albite	North Polar distance	73° 21′	Longitude West	119° 10′
Christianite	,, ,,	73° 42′	,, ,,	117° 21′
Oligoclase	,, ,,	73° 21′	,, ,,	119° 10′

The form 2 1 0; ∞ $\bar{P}$¦ 2 Naumann; 1 2 0 Miller; H[2] Brooke and Levy.

Axinite, South Polar distance 86° 14′ Longitude West 61° 7′

The form 2 $\bar{1}$ 0; ∞ ¦P 2 Naumann; $\bar{1}$ 2 0 Miller; G[2] Brooke and Levy.

Blue Vitriol, South Polar distance 77° 47′ Longitude West 104° 22′

The form 1 2 0; ∞ $\breve{P}$¦ 2 Naumann; 2 1 0 Miller; $H^{\frac{1}{2}}$ Brooke and Levy.

Babingtonite, North Polar distance 89° 35′ Longitude West 47° 10′

The form $\bar{1}$ 2 0; ∞ ¦$\breve{P}$ 2 Naumann; $\bar{2}$ 1 0 Miller; $G^{\frac{1}{2}}$ Brooke and Levy.

Blue Vitriol, North Polar distance 87° 24′ Longitude West 133° 5′

Doubly Oblique Prism, Third Order.—The doubly oblique prism of the third order may be drawn by pricking off the points D_1, C_1, H_1, G_1, D_2, C_2, H_2, and G_2 from Fig. 346, and joining them as in Fig. 352. It is similar in form, but differs both in magnitude and position, from that of the first order. It may be regarded as composed of three forms, each consisting of two parallel faces. $D_1 H_1 G_2 D_2$ and $C_1 G_1 C_2 H_2$ are the faces of the macro-pinacoid.

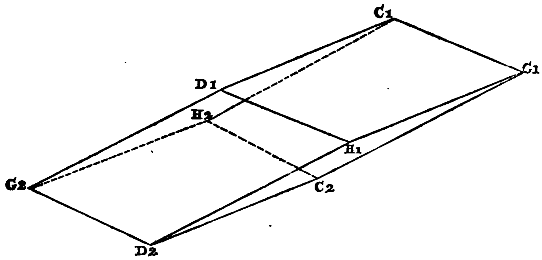


Fig. 352.

Symbols.—The faces of both the other forms cut the axes $P_1 P_2$ (Fig. 346), $T_1 T_2$ at the extremities of their parameters, and are parallel to the third axis $M_1 M_2$.

The symbol for the form whose faces are $D_1 C_1 H_1 G_1$ and $G_2 H_2 C_2 D_2$ is $1 \infty 1$; ${}_1\breve{P}^1 \infty$ Naumann; 1 0 1 Miller; F^1 Brooke and Levy.

The symbol for the form whose faces are $D_1 C_1 H_2 G_2$ and $H_1 G_1 C_2 D_2$ is $\bar{1} \infty 1$; ${}^1\breve{P}_1 \infty$ Naumann; $\bar{1}$ 0 1 Miller; B^1 Brooke and Levy.

The form $1 \infty 1$; ${}_1\breve{P}^1 \infty$ Naumann; 1 0 1 Miller; F^1 Brooke and Levy, occurs in

Albite	North Polar distance	52° 37′	Longitude	West	3° 8′
Axinite	,,	,,	56° 55′	,,	West	12° 36′
Blue Vitriol	,,	,,	29° 42′	,,	East	7° 4′
Christianite	,,	,,	51° 33′	,,	East	1° 19′
Oligoclase	,,	,,	52° 37′	,,	West	3° 8′
Sassoline	,,	,,	24° 21′	,,	East	0° 18′

Axinite has an imperfect cleavage parallel to this form.

The form $\bar{1} \infty 1$; ${}^1\breve{P}_1 \infty$ Naumann; $\bar{1}$ 0 1 Miller; B^1 Brooke and Levy.

Blue Vitriol	North Polar distance		20° 27′	Longitude	East	187° 4′
Sassoline	,,	,,	30° 28′	,,	West	179° 42′

Derived Doubly Oblique Prisms of the Third Order.—By making OP_1 and OP_2 in Fig. 346, m times the parameter OP (Fig. 342), and from the figure so altered obtaining a prism of the third order, another series of doubly oblique prisms similar in form and position, but differing in magnitude from Fig. 352, may be derived. m may be any whole number or fraction greater or less than unity.

Symbols.—The symbol for the form whose faces are $D_1 C_1 H_1 G_1$ and $G_2 H_2 C_2 D_2$, is $1 \infty m$; $m\,{}_1\breve{P}^1 \infty$ Naumann; m 0 1 Miller; $F^{\frac{1}{m}}$ Brooke and Levy.

The symbol for the form whose faces are $D_1 C_1 H_2 G_2$ and $H_1 G_1 C_2 D_2$, is $\bar{1} \infty m$; $m\,{}^1\breve{P}_1 \infty$ Naumann; $\bar{m}$ 0 1 Miller; $B^{\frac{1}{m}}$ Brooke and Levy.

The form $1 \infty \frac{3}{2}$; $\frac{3}{2}\,{}_1\breve{P}^1 \infty$ Naumann; 2 0 3 Miller; $F^{\frac{2}{3}}$ Brooke and Levy.

Christianite North Polar distance 34° 48′ Longitude East 1° 19′

The form $1\ \infty\ 2$; $2\ {}_1\breve{P}^1\ \infty$ Naumann; $2\ 0\ 1$ Miller; $F^{\frac{1}{2}}$ Brooke and Levy.

Albite	North Polar distance	82° 25′	Longitude	West	3° 8′
Blue Vitriol	,, ,,	57° 16′	,,	East	7° 4′
Christianite	,, ,,	81° 31′	,,	East	1° 19′
Labradorite	,, ,,	82° 25′	,,	West	3° 8′
Oligoclase	,, ,,	82° 25′	,,	West	3° 8′

The form $\bar{1}\ \infty\ 2$; $2\ {}^1\breve{P}_1\ \infty$ Naumann; $\bar{2}\ 0\ 1$ Miller; $B^{\frac{1}{2}}$ Brooke and Levy.

Christianite North Polar distance 41° 14′ Longitude West 178° 41′

The form $1\ \infty\ 3$; $3_1\ \breve{P}^1\ \infty$ Naumann; $3\ 0\ 1$ Miller; $F^{\frac{1}{3}}$ Brooke and Levy.

Blue Vitriol North Polar distance 74° 42′ Longitude East 7° 4′

Doubly Oblique Prism of the Fourth Order.—By pricking off the points $F_1, F_2, B_1, B_2, H_1, H_2, G_1$ and G_2 from Fig. 346, and joining them as in Fig. 353, a doubly oblique prism of the fourth order may be derived, similar in form but differing in magnitude and position from that of the first order. This prism is a combination of three forms, each consisting of a pair of parallel faces. $F_1\ H_1\ F_2\ G_1$ and $B_1\ H_2\ B_2\ G_2$ are regarded as faces of the *brachy-pinacoids*, being parallel to the axes $P_1\ P_2$ and $M_1\ M_2$ (Fig. 346).

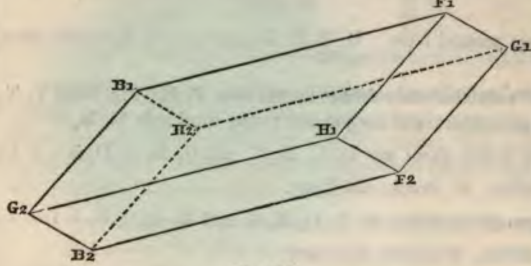


Fig. 353.

Symbols.—The faces of both the other forms cut the axes $P_1\ P_2$, $M_1\ M_2$, at the extremities of their parameters, and are parallel to the third axis $T_1\ T_2$ (Fig. 346).

The symbol for the form whose faces are $B_1\ F_1\ H_1\ G_2$ and $H_2\ G_1\ F_2\ B_2$ is $\infty\ 1\ 1$; ${}^1\bar{P}^1\ \infty$ Naumann; $0\ 1\ 1$ Miller; D^1 Brooke and Levy.

The symbol for the form whose faces are $B_1\ F_1\ G_1\ H_2$ and $G_2\ H_1\ F_2\ B_2$ is $\infty\ \bar{1}\ 1$; ${}_1\overline{P_1}\ \infty$ Naumann: $0\ \bar{1}\ 1$ Miller; C^1 Brooke and Levy.

The form $\infty\ 1\ 1$; ${}_1\bar{P}_1\ \infty$ Naumann; $0\ 1\ 1$ Miller; D^1 Brooke and Levy, occurs in—

Axinite	North polar distance	44° 43′	Longitude	West	90° 0′
Babingtonite	,, ,,	29° 35′	,,	,,	90° 0′
Blue Vitriol	,, ,,	50° 28′	,,	,,	90° 0′

Axinite has a cleavage parallel to this form.

The form $\infty\ \bar{1}\ 1$; ${}_1\bar{P}_1\ \infty$ Naumann; $0\ 1\ 1$ Miller; C^1 Brooke and Levy.

Axinite South polar distance 44° 48′ Longitude West 90° 0′

Derived Doubly Oblique Prisms of the Fourth Order.—By making OP_1 and OP_2 (Fig. 346) m times the parameter OP (Fig. 342), where m may be any whole number or fraction greater or less than unity; and from Fig. 346, so altered, obtaining a prism of the fourth order, a series of prisms may be derived, similar in form and position, but differing in magnitude from Fig. 353.

Symbols.—The symbol for the form whose faces are $B_1\ F_1\ H_1\ G_2$ and $H_2\ G_1\ F_2\ B_2$ is $\infty\ 1\ m$; $m\ {}_1\bar{P}_1\ \infty$ Naumann; $0\ m\ 1$ Miller; $D^{\frac{1}{m}}$ Brooke and Levy.

The symbol for the form whose faces are B_1 F_1 G_1 H_2 and G_2 H_1 F_2 B_2, is $\infty \bar{1} m$; $m\,{}_,\mathrm{P}_, \infty$ Naumann; $0\,\bar{m}\,1$ Miller; $C^{\frac{1}{m}}$ Brooke and Levy.

The form $\infty 1 \frac{1}{2}$; $\frac{1}{2}\,{}'\bar{\mathrm{P}}' \infty$ Naumann; 0 1 2 Miller; D^2 Brooke and Levy.

Axinite	North polar distance	26° 21′	Longitude West	90° 0′

The form $\infty 1 2$; $2\,{}'\bar{\mathrm{P}}' \infty$ Naumann; 0 2 1 Miller; $D^{\frac{1}{2}}$ Brooke and Levy.

Albite	North polar distance	42° 34′	Longitude West	90° 0′
Christianite	,, ,,	42° 38′	,, ,,	90° 0′
Oligoclase	,, ,,	42° 34′	,, ,,	90° 0′

The form $\infty \bar{1} 2$; $2\,{}_,\bar{\mathrm{P}}_, \infty$ Naumann; $0\,\bar{2}\,1$ Miller; $C^{\frac{1}{2}}$ Brooke and Levy.

Albite	North polar distance	46° 5′	Longitude East	90° 0′
Christianite	,, ,,	46° 47′	,, ,,	90° 0′
Oligoclase	,, ,,	46° 5′	,, ,,	90° 0′

Doubly Oblique Octahedron.—The *doubly oblique octahedron*, or the *triclinohedric pyramid*, is a solid bounded by eight scalene triangles. These triangular faces are only equal and similar to each other in pairs; every face, such as P_1 M_1 T_1 (Fig. 354), having a similar and equal face, P_2 M_2 T_2, parallel to it. This solid may be regarded as a combination of four open forms, each form consisting of a pair of similar and parallel faces. These forms are called *tetarto-pyramids*, and can only appear in combination with other forms.

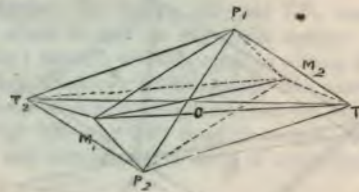


Fig. 354.

To draw the doubly oblique octahedron.—Prick off from Fig. 346 the points P_1, P_2, M_1, M_2, T_1 and T_2, and join them as in Fig. 354.

Axes.—The axes of the doubly oblique or anorthic system join the points P_1 P_2, M_1 M_2, and T_1 T_2 (Fig. 354).

Symbols.—Every face of the doubly oblique octahedron cuts the three axes P_1 P_2, M_1 M_2, and T_1 T_2 at the extremities of their parameters.

The symbol for the form whose faces are P_1 M_1 T_1 and P_2 M_2 T_2 is 1 1 1; P^1 Naumann; 1 1 1 Miller; O^1 Brooke and Levy.

The symbol for the form whose faces are P_1 M_1 T_2 and P_2 M_2 T_1 is $\bar{1}\,1\,1$; ${}^{\prime}\mathrm{P}$ Naumann; $\bar{1}\,1\,1$ Miller; E^1 Brooke and Levy.

The symbol for the form whose faces are P_1 M_2 T_2 and P_2 M_1 T_1 is $1\,1\,\bar{1}$; P_1 Naumann; $1\,1\,\bar{1}$ Miller; A^1 Brooke and Levy.

The symbol for the form whose faces are P_1 M_2 T_1 and P_2 M_1 T_2 is $\bar{1}\,1\,1$ ${}_1\mathrm{P}$ Naumann; $1\,\bar{1}\,1$ Miller; I^1 Brooke and Levy.

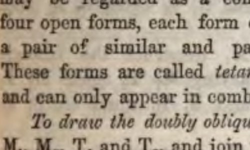


Fig. 355.

To describe a Net for the Doubly Oblique Octahedron.—Let α, β, and γ be the three angular elements given under those letters for a particular substance (page 458), whose octahedron is to be constructed.

Draw two lines OM_1, OP_1 (Fig. 355), making the angle α, with each other, produce OM_1 to M_2, make OM_1, OM_2 each equal to the parameter OM (Fig. 342) constructed for the particular substance, and OP_1 equal to the parameter OP (Fig. 342). Join P_1 M_1 and P_1 M_2.

Draw OP_1, OT_1 (Fig. 356), making the angle β with each other, produce OT_1 to T_2, make OT_1 and OT_2 equal to OT (Fig. 342), and OP_1 equal to OP (Fig. 342). Join $P_1\ T_1$ and $P_1\ T_2$.

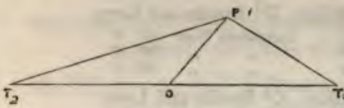


Fig. 356.

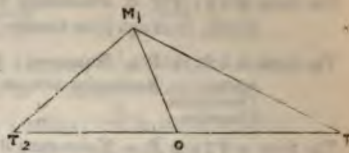


Fig. 357.

Also draw OT_1 and OM_1 (Fig. 357), making the angle γ with each other, produce OT_1 to T_2, make OT_1 and OT_2 equal to OT (Fig. 342), and OM_1 equal to OM (Fig. 342). Join $M_1\ T_1$ and $M_1\ T_2$.

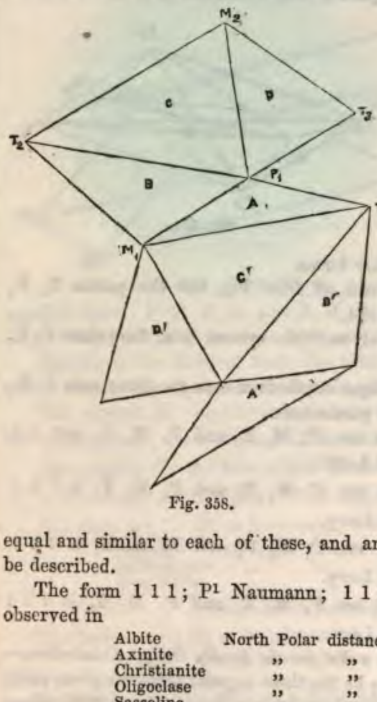


Fig. 358.

Then Fig. 358, draw $M_1\ T_1$ equal to $M_1\ T_1$ (Fig. 357), on it construct the triangle $M_1\ P_1\ T_1$ having its side $M_1\ P_1$ equal $M_1\ P_1$ (Fig. 355), and the remaining side $P_1\ T_1$ equal $P_1\ T_1$ (Fig. 356).

On $P_1\ M_1$ construct the triangle $P_1\ T_2\ M_1$, having $M_1\ T_2$ equal $M_1\ T_2$ (Fig. 357) and $P_1\ T_2$ equal to $P_1\ T_2$ (Fig. 356).

On $P_1\ T_2$ construct the triangle $P_1\ T_2\ M_2$ having $T_2\ M_2$ equal $T_1\ M_1$ (Fig. 357) and $P_1\ M_2$ equal $P_1\ M_2$ (Fig. 355).

On $P_1\ M_2$ construct the triangle $P_1\ M_2\ T_3$ having $M_2\ T_3$ equal $M_1\ T_2$ (Fig. 357) and $P_1\ T_3$ equal $P_1\ T_1$ (Fig. 356).

Then construct four other triangles equal and similar to each of these, and arrange them as in Fig. 358, and the net will be described.

The form 1 1 1; P[1] Naumann; 1 1 1 Miller; O[1] Brooke and Levy, has been observed in

Albite	North Polar distance		54° 44′	Longitude West		33° 50′
Axinite	,,	,,	64° 57′	,,	,,	45° 41′
Christianite	,,	,,	54° 22′	,,	,,	31° 33′
Oligoclase	,,	,,	54° 44′	,,	,,	33° 50′
Sassoline	,,	,,	41° 6′	,,	,,	59° 6′

The form $\bar{1}$ 1 1; [1]P Naumann; $\bar{1}$ 1 1 Miller; E[1] Brooke and Levy.

Axinite	North Polar distance		50° 36′	Longitude West		150° 1′
Blue Vitriol	,,	,,	48° 51′	,,	,,	116° 24′
Christianite	,,	,,	45° 14′	,,	,,	146° 35′
Sassoline	,,	,,	48° 0′	,,	,,	119° 55′

The form 1 1 $\bar{1}$; P_1 Naumann; 1 1 $\bar{1}$ Miller; A[1] Brooke and Levy.

Sassoline North Polar distance 50° 52′ Longitude East 120° 54′

The form $1\,\bar{1}\,1$; ${}_1P$ Naumann; $1\,\bar{1}\,1$ Miller; I^1 Brooke and Levy.

Albite	North	Polar distance	57° 37′	Longitude	East	29° 16′
Axinite	South	,, ,,	60° 0′	,,	West	150° 1′
Christianite	North	,, ,,	58° 10′	,,	East	33° 25′
Oligoclase	North	,, ,,	57° 37′	,,	East	29° 16′
Sassoline	North	,, ,,	42° 51′	,,	East	60° 5′

Angular Elements of the Anorthic System.—Five of the angular elements given in page 458 are necessary for the construction of any of the forms of the anorthic system; α is the inclination of the axis OP_1 (Fig. 340) to OM_1, β of the axis OP_1 to OT_1, and γ of the axis OM_1 to OT_1; A is the inclination of the plane $P_1\,OT_1$ to the plane $M_1\,OT_1$; B is the inclination of the plane $P_1\,OM_1$ to the plane $M_1\,OT_1$; and c is the inclination of the plane $P_1\,OM_1$ to the plane $P_1\,OT_1$; the remaining elements δ and ϵ depend upon the ratios which the unequal parameters OP_1, OM_1 and OT_1 bear to each other.

Derived Doubly Oblique Octahedrons.—By making OP_1 and OP_2 equal to m times the parameter OP (Fig. 342) where m may be any whole number or fraction greater, equal to, or less than unity; and OT_1 and OT_2 equal to n times the parameter OT (Fig. 342), where n is any whole number or fraction greater than unity, we may from Fig. 342 so altered derive a series of doubly oblique octahedrons, whose general symbol will be $n\,1\,m$. By making OM_1 and OM_2 equal to n times OM (Fig. 342) instead of OT_1 n times OT_1, we may obtain another series of octahedrons whose general symbol will be $1\,n\,m$.

Symbols for the Forms composing the Derived Octahedrons.

The symbols for the form $1\,1\,m$ are $m\,P^1$ Naumann; $m\,m\,1$ Miller; O^m Brooke and Levy.

For the form $\bar{1}\,1\,m$, $m\,{}^1P$ Naumann; $\bar{m}\,m\,1$ Miller; E^m Brooke and Levy.

For the form $1\,\bar{1}\,m$; $m\,{}_1P$ Naumann; $m\,\bar{m}\,1$ Miller; I^m Brooke and Levy.

For the form $1\,1\,\bar{m}$; $m\,P_1$ Naumann; $m\,m\,\bar{1}$ Miller; A^m Brooke and Levy.

For the form $1\,n\,1$; $\breve{P}_1\,n$ Naumann; $n\,1\,n$ Miller; ${}_nO$ Brooke and Levy.

For the form $\bar{1}\,n\,1$; ${}^1\breve{P}\,n$ Naumann; $\bar{n}\,1\,n$ Miller; ${}_nE$ Brooke and Levy.

For the form $1\,\bar{n}\,1$; ${}_1\breve{P}\,n$ Naumann; $n\,\bar{1}\,n$ Miller; ${}_nI$ Brooke and Levy.

For the form $1\,n\,\bar{1}$; $\breve{P}_1\,n$ Naumann; $n\,1\,\bar{n}$ Miller; ${}_nA$ Brooke and Levy.

For the form $n\,1\,1$; $\bar{P}^1\,n$ Naumann; $1\,n\,n$ Miller; O_n Brooke and Levy.

For the form $\bar{n}\,1\,1$; ${}^1\bar{P}\,n$ Naumann; $\bar{1}\,n\,n$ Miller; E_n Brooke and Levy.

For the form $n\,\bar{1}\,1$; ${}_1\bar{P}\,n$ Naumann; $1\,\bar{n}\,n$ Miller; I_n Brooke and Levy.

For the form $n\,1\,\bar{1}$; $P_1\,n$ Naumann; $1\,n\,\bar{n}$ Miller; A_n Brooke and Levy.

For the form $1\,n\,m$; $m\,\breve{P}^1\,n$ Naumann; $h\,k\,l$ Miller; $D^{\frac{1}{h}}\,F^{\frac{1}{k}}\,H^{\frac{1}{l}}$ Brooke and Levy.

For the form $\bar{1}\,n\,m$; $m\,{}^1\breve{P}\,n$ Naumann; $\bar{h}\,k\,l$ Miller; $B^{\frac{1}{h}}\,D^{\frac{1}{k}}\,G^{\frac{1}{l}}$ Brooke and Levy.

For the form $1\,\bar{n}\,m$; $m\,{}_1\breve{P}\,n$ Naumann; $h\,\bar{k}\,l$ Miller; $F^{\frac{1}{h}}\,C^{\frac{1}{k}}\,G^{\frac{1}{l}}$ Brooke and Levy.

For the form $1\,n\,\bar{m}$; $m\,\breve{P}_1\,n$ Naumann; $h\,k\,\bar{l}$ Miller; $C^{\frac{1}{h}}\,B^{\frac{1}{k}}\,H^{\frac{1}{l}}$ Brooke and Levy.

For the form $n\,1\,m$; $m\,\bar{P}^1\,n$ Naumann; $h\,k\,l$ Miller; $D^{\frac{1}{h}}\,F^{\frac{1}{k}}\,H^{\frac{1}{l}}$ Brooke and Levy.

For the form $\bar{n}\ 1\ m$; $m\ {}^1\bar{P}\ n$ Naumann; $\bar{h}\ k\ l$ Miller; $B^{\frac{1}{h}}\ D^{\frac{1}{k}}\ G^{\frac{1}{l}}$ Brooke and Levy.

For the form $n\ \bar{1}\ m$; $m\ {}_1\bar{P}\ n$ Naumann; $h\ \bar{k}\ l$ Miller; $F^{\frac{1}{h}}\ C^{\frac{1}{k}}\ G^{\frac{1}{l}}$ Brooke and Levy.

For the form $n\ 1\ \bar{m}$; $m\ \bar{P}_1\ n$ Naumann; $h\ k\ \bar{l}$ Miller; $C^{\frac{1}{h}}\ B^{\frac{1}{k}}\ H^{\frac{1}{l}}$ Brooke and Levy.

The relation between the symbols $h\ k\ l$, and $1\ n\ m$, is that the former are the numerators of the reciprocals of the latter reduced to a common denominator.

The form $1\ 1\ \frac{1}{2}$; $\frac{1}{2}\ P^1$ Naumann; $1\ 1\ 2$ Miller; $O^{\frac{1}{2}}$ Brooke and Levy occurs in
Albite North Polar distance 29° 50′ Longitude West 33° 50′

The form $1\ \bar{1}\ \frac{1}{2}$; $\frac{1}{2}\ {}_1P$ Naumann; $1\ \bar{1}\ 2$ Miller; $I^{\frac{1}{2}}$ Brooke and Levy.
Albite North Polar distance 29° 55′ Longitude East 29° 16′
Axinite South " " 38° 4′ " West 150° 1′

The form $1\ \bar{1}\ 2$; $2\ {}_1P$ Naumann; $2\ \bar{2}\ 1$ Miller; I^2 Brooke and Levy.
Christianite North Polar distance 85° 7′ Longitude East 33° 25′
Oligoclase South " " 85° 17′ " " 29° 16′

The form $1\ 3\ 3$; $3\ \breve{P}^1\ 3$ Naumann; $3\ 1\ 1$ Miller; $D^{\frac{1}{3}}\ F^1\ H^1$ Brooke and Levy.
Blue Vitriol North Polar distance 86° 23′ Longitude West 26° 51′

The form $\bar{1}\ 2\ 2$; $2\ {}^1\breve{P}\ 2$ Naumann; $\bar{2}\ 1\ 1$ Miller, $B^{\frac{1}{2}}\ D^1\ G^1$ Brooke and Levy.
Blue Vitriol North Polar distance 51° 1′ Longitude West 133° 5′

The form $1\ \bar{2}\ 2$; $2\ {}_1\breve{P}\ 2$ Naumann; $2\ \bar{1}\ 1$ Miller; $F^{\frac{1}{2}}\ C^1\ G^1$ Brooke and Levy.
Axinite South Polar distance 75° 27′ Longitude West 169° 59′

The form $2\ 1\ 4$; $4\ \bar{P}^1\ 2$ Naumann; $2\ 4\ 1$ Miller; $D^{\frac{1}{2}}\ F^{\frac{1}{4}}\ H^1$ Brooke and Levy.
Christianite North Polar distance 81° 23′ Longitude West 51° 21′

The form $2\ \bar{1}\ 4$; $4\ {}_1\bar{P}\ 2$ Naumann; $2\ \bar{4}\ 1$ Miller; $F^{\frac{1}{2}}\ C^{\frac{1}{4}}\ G^1$ Brooke and Levy.
Christianite North Polar distance 88° 4′ Longitude East 55° 22′

The form $2\ 1\ 2$; $2\ \bar{P}^1\ 2$ Naumann; $1\ 2\ 1$ Miller; $D^1\ F^{\frac{1}{2}}\ H^1$ Brooke and Levy.
Axinite North Polar distance 72° 9′ Longitude West 61° 17′

The form $3\ 1\ 3$; $3\ \bar{P}^1\ 3$ Naumann; $1\ 3\ 1$ Miller; $D^1\ F^{\frac{1}{3}}\ H^1$ Brooke and Levy.
Axinite North Polar distance 76° 34′ Longitude West 69° 8′

To determine the position of the poles of any form on the sphere of projection.—If h, k and l be Miller's symbols for any face, and λ the north polar distance of the pole of one of its faces on the sphere of projection, and μ the longitude of that pole, west from the point where the axis $O\,T_1$ cuts the sphere, the point where the axis $O\,Z$ cuts the sphere, or the pole of the face $\infty\,\infty\,1$, being taken as the north pole of the sphere.

$$\tan\phi = \frac{h}{k}\cos\gamma\tan\delta \qquad q = k\cos(45+\varphi)\cot\delta\ \mathrm{cosec}\,\gamma\sec 45\sec\phi$$

$$\tan\theta = \frac{h}{l}\cos\beta\tan\epsilon \qquad q' = l\cos(45+\theta)\cot\epsilon\ \mathrm{cosec}\,\beta\sec 45\sec\theta$$

$$\tan\psi = \frac{q}{q'}\cos A \qquad r = q'\cos(45+\psi)\ \mathrm{cosec}\,A\sec 45\sec\psi$$

$$\tan\mu = \frac{q}{h} \qquad \tan\lambda = \frac{h}{r}\sec\mu$$

When $h = o$ and $k = o$ then $q = o$; when $h = o$ and $l = o$ then $q' = o$; and when $q = o$ and $q' = o$, then $r = o$. θ, ϕ and ψ are subsidiary angles.

TWIN CRYSTALS.

win Crystal, or *Macle Crystal*, is composed of two crystals, or similar portions of stals joined together in such a manner that one would come into the position

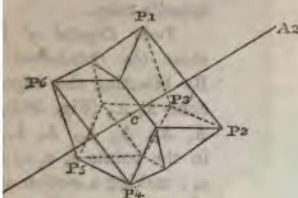


Fig. 359.

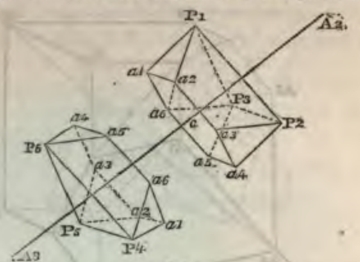


Fig. 360.

her by revolving through two right angles round an axis which is perpendicular ane, which either is, or may be, a either crystal. From this property, ystals are called *hemitrope crystals*, by

axis about which the crystals are l to revolve is called the twin axis, plane to which it is perpendicular plane.

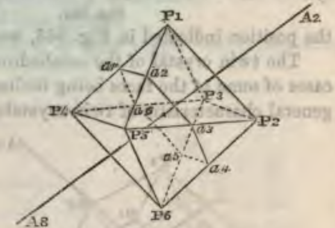


Fig. 361.

Crystal of the Octahedron about the al Axis.—If we bisect the edges $P_1 P_4$ 31), $P_1 P_5$, $P_5 P_2$, $P_2 P_6$, $P_3 P_6$, and the octahedron $P_1 P_5 P_6$, by the points a_1, a_2, a_3, a_4, a_5 and a_6, and join these points; then suppose the octahedron cut in half by a plane passing through $a_1\ a_2\ a_3\ a_4\ a_5\ a_6$, and a wire axis or pin passed through the centre of the octahedron perpendicular to the plane $a_1 a_2 a_3\ a_4 a_5 a_6$. This axis will correspond to the octahedral axis $A_2\ A_8$ (Fig. 17), if the octahedron be inscribed in a cube, as in Fig. 21.

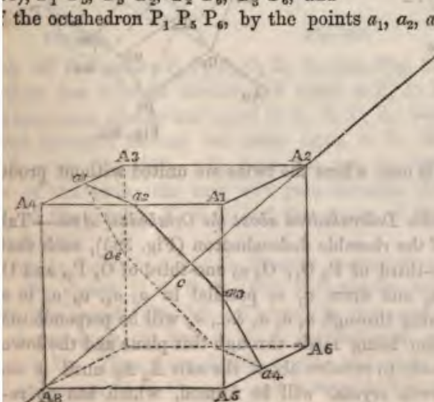


Fig. 362.

Let now the lower portion of the octahedron be separated from the upper and made to revolve through an angle of 180°, round the axis A_2 A_8, till it comes successively into the position shown in Figs. 360 and 359; and a *twin crystal* will be formed. The plane $a_1\ a_2$ &c. a_6, is the twin plane, and the line $A_2\ A_8$, which is perpendicular to it, the twin axis.

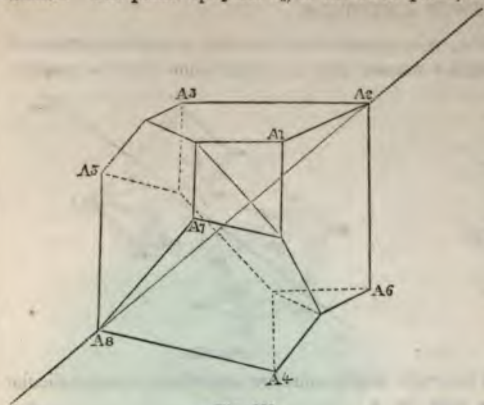


Fig. 363.

This twin crystal is of frequent occurrence among crystals of the diamond and the spinelle ruby.

Twin Crystal of the Cube about the Octahedral Axis.—By bisecting the edges of the cube $A_4\ A_3$ (Fig. 362), $A_1\ A_4$, $A_1\ A_5$, $A_5\ A_6$, $A_6\ A_7$, $A_7\ A_3$, in the points $a_1\ a_2\ a_3\ a_4\ a_5$ and a_6; making a section of it by a plane passing through these points, and causing the lower section to revolve through an angle of 180° round the axis $A_2\ A_8$, when it will come into the position indicated in Fig. 363, we shall obtain a twin crystal of the cube.

The twin crystal of the octahedron (Fig. 361), and of the cube (Fig. 363), present cases of some of the faces being inclined to each other at re-entering angles. This is a general characteristic of twin crystals; though there are instances, of which the twin

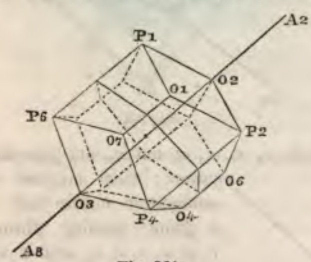


Fig. 364.

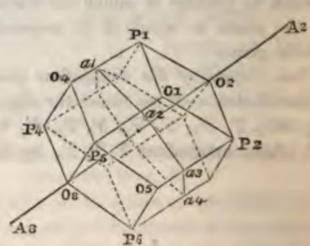


Fig. 365.

of the rhombic dodecahedron is one, where the twins are united without producing re-entering angles.

Twin Crystals of the Rhombic Dodecahedron about the Octahedral Axis.—Take points $a_1\ a_2\ a_3$ and a_4 on the edges of the rhombic dodecahedron (Fig. 365), such that $O_4\ a_1$ is one-third of $P_1\ O_4$; $O_1\ a_2$ one-third of $P_5\ O_1$; $O_5\ a_3$ one-third of $O_5\ P_2$, and $O_6\ a_4$ one-third of $O_6\ P_6$; join $a_1\ a_2\ a_3$ and draw $a_1\ a_6$ parallel to $a_3\ a_4$, $a_6\ a_5$ to $a_2\ a_3$, and $a_5\ a_4$ to $a_1\ a_2$. The plane passing through $a_1\ a_2\ a_3$ &c., a_6 will be perpendicular to the octahedral axis $A_2\ A_8$; a section being made through this plane and the lower part of the rhombic dodecahedron made to revolve about the axis $A_2\ A_8$ until it comes into the position (Fig. 364), a twin crystal will be formed, which has no re-entering angles.

It is not essential that the members of a twin crystal should be exactly the half of the form from which they are derived. Thus two sections of the octahedron, similar to that shown in Fig. 11, may be united to form a twin. Sometimes the two members of the twin may both be completely formed, so as to produce the appearance of two crystals penetrating one another. Thus Fig. 366 represents each cube in Fig. 363

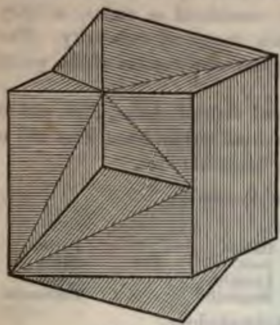


Fig. 366.

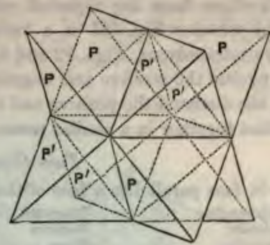
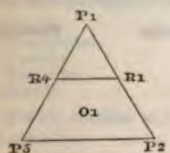


Fig. 367.

completed, and forming, as it were, two cubes penetrating each other. This form of twin crystal is frequently found in fluor spar and iron pyrites.

Fig. 367 represents two octahedrons of fahlerz, or gray copper ore, intersecting each other, and forming a twin crystal.

Nets for Twin Crystals of the Octahedron.



Fin. 368.

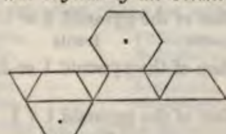


Fig. 369.

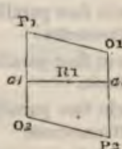


Fig. 370.

Prick off the points P_1 P_5 P_2 O_1 R_1 R_4 from Fig. 22; join P_1 P_5, P_5 P_2, P_1 P_2 and R_4 R_1, then one triangle similar and equal to P_1 P_5 P_2, three equal to P_1 R_4 R_1 and three trapeziums similar and equal to R_1 R_4 P_5 P_2, and a regular hexagon having its sides equal to R_1 R_4 arranged as in Fig. 369; will form the net for one member of the twin; the axis will pass through the point O_1 of the triangle P_1 P_5 P_2 and the centre of the hexagonal face.

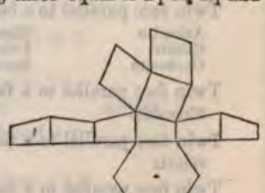


Fig. 371.

Net for the Twin Crystal of the Rhombic Dodecahedron.—Draw the rhomb P_1 O_1 O_2 P_2 (Fig. 370) similar and equal to the rhomb (Fig. 30). Through R_1 the centre of the rhomb draw the line a_1 R_1 a_2 perpendicular to P_1 O_2 or O_1 P_2. Then three rhombs similar and equal to P_1 O_2 P_2 O_1; six trapeziums similar and equal to P_1 O_1 a_2 a_1, and a regular hexagon having its sides equal to a_1 a_2, arranged as in Fig. 371, will form a net for one member of the twin. The twin axis will pass through the point where the three rhombs meet, and the centre of the hexagonal face.

When the crystallographic axes of the two members of the twin crystal are para to each other, as in the case of the twin, Fig. 367, so that the cleavages of the one parallel to or continued one into the other without interruption; we cannot determ with certainty whether such crystals are to be considered as twins, or only sin crystals whose faces are repeated with a certain degree of regularity. Thus it doubtful whether Fig. 367 is a twin, or a regular combination of the positive a negative tetrahedrons, Figs. 92 and 93.

In pyrites the positive and negative pentagonal dodecahedrons, Figs. 113 and 11 and in the diamond the positive and negative six-faced tetrahedrons, Figs. 107 and 10 are united together in a similar manner, forming doubtful twins.

Twin Crystals, Cubical System.

Twin face parallel to a face of the octahedron.

Alabandine	Diamond	Galena	Pyrite
Blende	Fahlerz	Gold	Silver
Bornite	Fluor	Linneite	Spinelle
Copper	Gahnite	Magnetite	Tennantite

Twin face parallel to a face of the rhombic dodecahedron.

Diamond   Eulytine   Fahlerz   Pyrite

Twin Crystals Pyramidal System.

Twin face parallel to a face of the square prism 1 ∞ ∞.

Towanite

Twin face parallel to a face of the square prism 1 1 ∞.

Scheelite

Twin face parallel to a face of the pyramid 1 ∞ 1.

Cassiterite   Fanjasite   Rutile   Scheelite   Towanite

Twin face parallel to a face of the pyramid 1 ∞ 3.

Rutile

Twin face parallel to a face of the pyramid 1 1 1.

Hansmunnite   Tin   Towanite

Twin face parallel to a face of the pyramid 1 1 3.

Tin

Twin Crystals Rhombohedral System.

Twin face parallel to a face of the basal pinacoid ∞ ∞ 1.

Ankerite	Cinnabar	Hematite	Levine
Calcite	Dolomite	Ilmenite	Pyrargyrite
Chabasite	Gmelinite	Ice	Quartz

Twin face parallel to a face of the hexagonal prism of the second order 1 1 ∞.

Phenakite

Twin face parallel to a face of the six-faced pyramid of the first order 1 2 1.

Quartz

Twin face parallel to a face of the positive rhomboid + R.

Calcite   Corundum   Hematite   Quartz   Pyrargyrite

Twin face parallel to a face of the positive rhomboid $+\frac{1}{4}$ R.

Tetradymite   Pyrargyrite

Twin face parallel to a face of the negative rhomboid $-\frac{1}{2}$ R.

Ankerite	Bismuth	Chalybite
Arsenic	Calcite	Dioptase

Twin face parallel to a face of the negative rhomboid — 2 R.

Calcite

The following figures show some of the beautiful forms assumed by twin crystals of ice or snow.

Twin Crystals—Prismatic System.

Twin-face parallel to a face of the macro-pinacoid $\infty\ 1\ \infty$.
Wolfram.

Twin-face parallel to a face of the brachy-pinacoid $1\ \infty\ \infty$.
Struvite.

Twin-face parallel to a face of the prism of the 1st order $1\ 1\ \infty$.

Alstonite.	Epistilbite.	Phillipsite.	Stromeyerite.
Antimonsilber.	Glaserite.	Redruthite.	Sulphur.
Aragonite.	Harmotome.	Sternbergite.	Witherite.
Bournonite.	Marcasite.	Stephanite.	Zinckenite.
Cerussite.	Mispickel.	Strontianite.	

Twin-face parallel to a face of the prism of the 2nd order $1\ \infty\ 1$.
Chrysoberyl. **Leadhillite.** **Manganite.**

Twin-face parallel to a face of the prism of the 2nd order $1\ \infty\ \frac{3}{2}$.
Staurolite.

Twin-face parallel to a face of the prism of the 2nd order $1\ \infty\ 2$.
Niobite.

Twin-face parallel to a face of the prism of the 2nd order $1\ \infty\ \frac{5}{3}$.
Wolfram.

Twin-face parallel to a face of the prism of the 3rd order $\infty\ 1\ 1$.
Marcasite. **Mispickel.** **Smithsonite.** **Stilbite.**

Twin-face parallel to a face of the pyramid cf the 1st class $1\ 1\ \frac{1}{2}$.
Redruthite. **Stromeyerite.**

Twin-face parallel to a face of the pyramid of the 2nd class $1\ \frac{3}{2}\ \frac{3}{2}$.
Staurolite.

Twin Crystals—Oblique System.

Twin-face parallel to a face of the basal pinacoid $\infty\ \infty\ 1$.
Epidote. **Felspar.** **Mirabilite.** **Sphene.**

Twin-face parallel to a face of the ortho-pinacoid $1\ \infty\ \infty$.

Acmite.	Felspar.	Gypsum.	Rhyacolite.
...le.	Feuerblende.	Linarite.	Scolezite.
	Freieslebenite.	Malachite.	Vauquelinite.

Twin-face parallel to a face of the prism 3 1 ∞.
Felspar.

Twin-face parallel to a face of the prism 1 ∞ 1.
Chessylite. Gypsum. Natron. Sphene. Whewellite.

Twin-face parallel to a face of the prism 1 ∞ 2.
Humite.

Twin-face parallel to a face of the prism ∞ 1 1.
Woolastonite.

Twin-face parallel to a face of the prism ∞ 1 2.
Felspar. Rhyacolite.

Twin Crystals—Anorthic System.

Twin-face parallel to a face of the basal-pinacoid ∞ ∞ 1.
Labradorite.

Twin-face parallel to a face of the macro-pinacoid ∞ 1 ∞.
Albite. Christianite. Labradorite. Oligoclase.

Twin-axis perpendicular to the plane passing through the poles of the forms $\bar{1}$ 1 ∞, ∞ 1 ∞, and 1 1 ∞.
Albite.

Twin-axis perpendicular to a face of the plane passing through the poles of the forms ∞ ∞ 1, 1 ∞ 1, and 1 ∞ 2.
Albite. Oligoclase.

Twin-axis perpendicular to a face of the plane passing through the poles of the forms 1 ∞ ∞, 1 1 ∞, and $\bar{1}$ 1 ∞.
Sassoline.

Pseudomorphous Crystals.—Pseudomorphous crystals are those which present the form of a mineral differing from that of which they are composed. They may be produced by the decomposition of the crystal after it has been formed, or by another substance being deposited upon it so as to assume its form. Sometimes after another substance has been deposited on a crystal, the crystal may have been removed, and a third mineral deposited in its cast.

The following is a list of pseudomorphous substances quoted by Professor Miller from Blum:—

Pseudomorphous by Loss of an Ingredient.

Calcite	replacing crystals of	Gaylussite.
Quartz	,,	Heulandite and Stilbite.
Kyanite	,,	Andalusite.
Steatite	,,	Amphibole.
Copper	,,	Cuprite.
Argentite	,,	Pyrargyrite.

Pseudomorphous by the Addition of an Ingredient.

Gypsum	replacing crystals of	Karstenite.
Mica	,,	Pinite.
Valentinite	,,	Antimony.
Anglesite	,,	Galena.
Hematite	,,	Magnetite.
Limonite	,,	Hematite.
Malachite	,,	Cuprite.
Bornite and Towanite	,,	Redruthite.

Pseudomorphous by Exchange of Ingredients.

Baryte	replacing crystals of	Witherite and Barytocalcite.
Fluor and Gypsum	"	Calcite.
Calcite	"	Gypsum.
Magnesite	"	Calcite.
Calcedony	"	Datholite.
Jasper	"	Amphibole.
Opal and Cimolite	"	Augite.
Lithomarge	"	Topaz, Felspar, and Nepheline.
Kaolin	"	Felspar, Porzellanspath, and Leucite.
Mica	"	Andalusite, Felspar, Scapolite, and Tourmaline.
Mica, Hardfahlunite, Aspasiolite, Fahlunite, Esmarkite, Bonsdorffite, Chlorophyllite, Weissite, Plaseolite, Pyrargillite, Gigantollite, and Pinite	"	Cordierite.
Prehnite	"	Analcine, Mesotype, and Leonhardite.
Talc	"	Chiastolite, Kyanite, Couzeranite, Felspar, and Pyrope.
Stealite	"	Magnesite, Spinelle, Quartz, Andalusite, Chiastolite, Topaz, Felspar, Mica, Scapolite, Tourmaline, Staurolite, Garnet, Idocrase, and Augite.
Serpentine	"	Spinelle, Mica, Garnet, Augite, Chondrodite, Amphibole, and Olivine.
Amphibole	"	Augite.
Chlorite	"	Felspar, Garnet, and Amphibole.
Pyrolusite, Hausmannite, Manganite, Valentinite, Stibiolite, and Kermes	"	Antimonite.
Wismuthocker	"	Patrinite.
Minium	"	Galena and Cerussite.
Galena	"	Pyromorphite.
Pyromorphite	"	Galena and Cerussite.
Cerussite	"	Galena, Anglesite, Leadhillite.
Wulfenite	"	Galena.
Magnetite	"	Chalybite.
Hematite	"	Göthite, Pyrite, Pharmacosiderite, and Chalybite.
Limonite	"	Marcasite, Skorodite, and Chalybite.
Stilpnosiderite	"	Vivianite.
Pyrite	"	Mispickel.
Melanterite	"	Pyrite.
Grünerde	"	Augite.
Pseudotriplite	"	Triphyline.
Wolfram	"	Scheelite.
Erythrine	"	Smaltite.
Kupferschwärze	"	Redruthite.
Kupferpecherz	"	Towanite, and Fahlerz.
Coveline	"	Towanite.
Malachite	"	Chessylite, Towanite, and Fahlerz.
Chessylite	"	Fahlerz.

Pseudomorphous by total Change of Substance.

Graphite	replacing crystals of	Pyrite.
Salt	"	Magnesite.
Karstenite, Gypsum, and Polyhalite	"	Salt.
Quartz	"	Baryte, Fluor, Gypsum, Calcite, Barytocalcite, Magnesite, Scheelite, Galena, Cerussite, Hematite, Pyrite, and Chalybite.
Prasen and Eisenkiesel	"	Calcite.
Chalcedony	"	Baryte, Fluor, Calcite, Magnesite, and Pyromorphite.
Carnelian	"	Calcite.
Hornstone	"	Fluor, Calcite, Mica, and Chalybite.
Semiopal	"	Calcite.
Lithomarge	"	Fluor.
Pyrite	"	Quartz, Stephanite, and Pyrargyrite.

Marcasite	replacing crystals of	Pyrargyrite.
Chalybite	,,	Baryte, Calcite, and Magnesite.
Malachite	,,	Calcite and Cerussite.
Crysocolla	,,	Cerussite.
Feldstine, Meerschaum, and Pyrolusite	,,	Calcite.
Pyrolusite	,,	Magnesite.
Hausmannite and Manganite	,,	Calcite.
Psilomelane	,,	Baryte, Fluor, and Pharmacosiderite.
Smithsonite	,,	Fluor, Calcite, Magnesite, Galena, and Pyromorphite.
Kassiterite	,,	Felspar.
Cerussite	,,	Baryte and Fluor.
Stilpnosiderite	,,	Magnesite and Calamine.
Hematite	,,	Fluor and Calcite.
Limonite	,,	Baryte, Fluor, Calcite, Magnesite, Quartz, Comptonite, Blende, Galena, Pyromorphite, Cerussite, and Cuprite.
Pyrite	,,	Baryte and Calcite.
Marcasite	,,	Fluor and Calcite.

Pseudomorphism of dimorphous substances.

Calcite	replacing crystals of	Aragonite.
Marcasite	,,	Pyrite.

Pseudomorphism after organic forms.

Calcite, Baryte, Celestine, Fluor, Gypsum, Quartz, Opal, Talc, Pyrite, Hematite, Limonite, Chalybite, Blende, Galena, Cerussite, Copper, Towanite, Bornite, Redruthite, and Cinnabar.

Dimorphism.—Bodies of the same chemical composition, which crystallize in forms belonging to two different systems, or if in the same system in forms which can only be referred to two different sets of parameters, which will be indicated by their having different angular elements, are said to be *dimorphous.* Sulphur and carbonate of lime are instances of dimorphous substances, the system of crystallization to which each of these will belong seems to depend upon the temperature at which the crystal is formed. Titanic acid is tri-morphous, as Brookite it is prismatic, as Anatase and Rutile it is pyramidal, but the angular elements of Anatase and Rutile differ.

Isomorphism—Substances forming crystals belonging to the same system, if their angular elements differ but a few minutes, are said to be *isomorphous, homœomorphous,* or *plesiomorphous.* Alumina, red oxide of iron, and oxide of chrome; carbonates of lime (calcite), of magnesia (magnesite), of protoxide of iron (chalybite), of protoxide of manganese (diallogite), of oxide of zinc: antimony, bismuth, arsenic, and tellurium form three isomorphous groups of the rhombohedral system. Carbonate of lime (aragonite), of barytes, of strontian, and of oxide of lead; Sulphate of potash, seleniate of potash, chromate of potash, and manganate of potash; sulphate of soda, seleniate of soda, sulphate of oxide of silver, and seleniate of oxide of silver, are three isomorphous groups of the prismatic system. Gypsum, sulphate of iron, and seleniate of iron is an isomorphous group of the oblique system. Seleniate of oxide of copper, sulphate of oxide of copper, and sulphate of protoxide of manganese are isomorphous forms of the anorthic system.

Any chemical elements or compound substances which will replace each other without altering the crystallographic character of the compound in which the change takes place, are also said to be *isomorphous.* Thus in the garnets and alums, iron, calcium, magnesium, and aluminium replace each other, and are therefore said to be isomorphous.

Goniometers.—Instruments which enable us to determine the angles at which adjacent faces of crystals are inclined to each other, are called *goniometers.* Professor Miller's description of the method of using them having been given in the chemical department of this work, we here quote Mr. Brooke's, from the "Encyclopædia Metropolitana:"—

"The mutual inclination of any two planes, as of *a* and *b*, Fig. 372, is indicated by the angle formed by two lines, *e d*, *e f*, drawn upon them from any point *e* on the edge at which they meet, and perpendicular to that edge.

"Now it is known that if two right lines, as *g f*, *d h*, Fig. 373 cross each other at any point *e*, the opposite angles *d e f*, *g e h*, are equal. If, therefore, the lines, *g f*, *d h*, are supposed to be very thin and narrow plates, and to be attached together

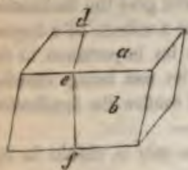


Fig. 372.

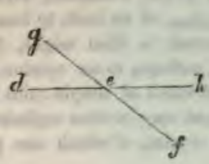


Fig. 373.

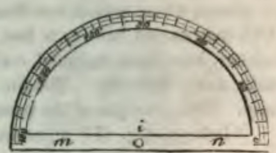


Fig. 374.

by a pin at *e*, serving as an axis to permit the point, *f*, to be brought nearer either to *d*, or to *h*, and that the edges, *e d*, *e f*, of those plates, are applied to the planes of the crystal, Fig. 372, so as to rest upon the lines, *e d*, *e f*, it is obvious that the angle, *g e h*, of the moveable plates would be exactly equal to the angle, *d e f*, of the crystal.

"The common goniometer is a small instrument for measuring this angle, *g e h*, of the moveable plates. It consists of a semicircle, Fig. 374, divided into 360 equal parts, or half degrees, and a pair of moveable arms, *d h*, *g f*, Fig. 375, the semicircle having a pin at *i*, which fits into a hole in the moveable arms at *e*.

"The method of using this instrument is to apply the edges, *d e*, *e f*, of the moveable arms to the two adjacent planes of any crystals, so that they shall actually touch or rest upon those planes *in directions perpendicular to their edge.* The arm, *d h*, is

Fig. 375.

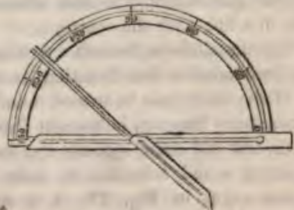


Fig. 376.

then to be laid on the plate, *m n*, of the semicircle, Fig. 374, the hole at *e* being suffered to drop on the pin at *i*, and the edge nearest to *h* of the arm *g e* will then indicate on the semicircle, as in Fig. 376, the number of degrees which the measured angle contains.

"When this instrument is applied to the planes of a crystal, the points, *d* and *f*, Fig. 375, should be previously brought sufficiently near together for the edges, *d e*, *e f*, to form a more acute angle than that about to be measured. The edges being then gently pressed upon the crystal, the points, *d* and *f*, will be gradually separated, until the edges coincide so accurately with the planes that no light can be perceived between them.

"The common goniometer is, however, incapable of affording very precise results, owing to the occasional imperfection of the planes of crystals, their frequent minuteness, and the difficulty of applying the instrument with the requisite degree of precision.

"The more perfect instrument, and one of the highest value to crystallography, is the reflecting goniometer, invented by Dr. Wollaston, which will give the inclination of planes whose area is less than $\frac{1}{100000}$ of an inch, to less than a minute of a degree. This instrument has been less resorted to than might, from its importance to the science, have been expected, owing, perhaps, to an opinion of its use being attended with some difficulty. But the observance of simple rules will render its application easy. The principle of the instrument may be thus explained:—

"Let *a b*, Fig. 377 represent a crystal, of which one plane only is visible in the

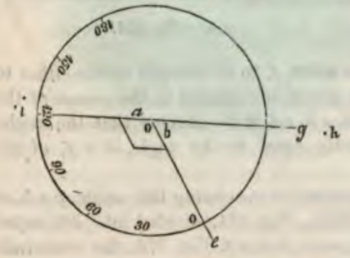


Fig. 377.

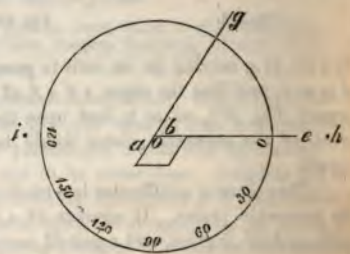


Fig. 378.

figure, attached to a circle, graduated on its edge, and moveable on its axis at *o*; and let *a* and *b* mark the position of the two planes whose mutual inclination is required.

"And let the lines, *o e*, *o g*, represent imaginary lines, resting on those planes in directions perpendicular to their common edge, and the dots at *i* and *h*, some permanent marks in a line with the centre, *o*.

"Let the circle be in such a position that the line, *o e*, would pass through the dot at *h*, if extended in that direction, as in Fig. 378.

"If the circle now be turned round with its attached crystal, as in Fig. 377, until the imaginary line, *o g*, is brought into the position of the line, *o e*, in Fig. 378, the number 120 will stand opposite the dot at *i*. This is the number of degrees at which the planes *a* and *b* incline to each other. For if the line *o g* be extended in the direction *o i*, as in Fig. 377, it is obvious that the lines, *o e*, *o i*, which are perpendicular to the common edge of the planes, *a* and *b*, would intercept exactly 120° of the circle.

"Hence an instrument constructed upon the principle of these diagrams is capable of giving with accuracy the mutual inclination of any two planes which reflect objects with sufficient distinctness, if the means can be found for placing them successively in the relative positions shown in the two preceding figures.

"This purpose is effected by causing an object, as the line at *m* (Fig. 379), to be reflected successively from the two planes, *a* and *b*, at the same angle. It is well known that the images of objects are reflected from bright planes at the same angle as that at which their rays fall on those planes; and that when the image of an object reflected from a horizontal plane is observed, it appears so much below the reflecting surface as the object itself is above.

"If, therefore, the planes *a* and *b* (Fig. 379) are successively brought into such positions as will cause the reflection of the line at *m*, from each plane, to

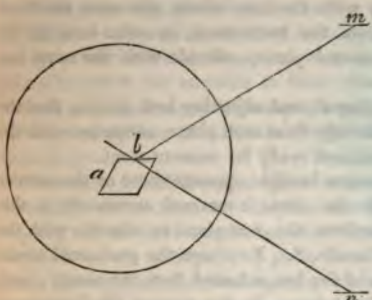


Fig. 379.

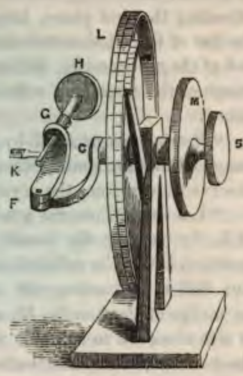


Fig. 380.

appear to coincide with another line at *n*, both planes will be successively placed in the relative positions of the corresponding planes in Figs. 377 and 378. To bring the planes of any crystal successively into these relative positions, the following directions will be found useful.

"The instrument, as shown in the sketch (Fig. 380) should be first placed on a pyramidal stand, and the stand on a small steady table, about six to ten or twelve feet from a flat window. The graduated circular plate should stand perpendicularly from the window, the pin GH being horizontal, not in the direction of the axis, as it is usually figured, but with the slit end nearest to the eye.

"Place the crystal which is to be measured on the table, resting on one of the two planes whose inclination is required, and with the edge, at which those planes meet, nearest and parallel to the window.

"Attach a portion of wax, about the size of *d*, to one side of a small brass plate, *e* (Fig. 381); lay the plate on the table with the edge, *f*, parallel to the window, the side to which the wax is attached being uppermost, and press the end of the wax against the crystal until it adheres; then lift the plate with its attached crystal, and place it in the slit of the pin GH, with that side uppermost which rested on the table.

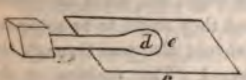


Fig. 381.

"Bring the eye now so near the crystal, as, without perceiving the crystal itself, to permit the images of objects reflected from its planes to be distinctly observed, and raise or lower that end of the pin GH which has the small circular plate on it, until one of the horizontal upper bars of the window is seen reflected from the upper or first plane of the crystal, corresponding with the plane *a* (Fig. 377), and until the image of the bar appears to touch some line below the window, as the edge of the skirting-board where it joins the floor.

"Turn the pin GH on its own axis also, if necessary, until the reflected image of the bar of the window coincides accurately with the observed line below the window.

"Turn now the small circular handle, S, on its axis, until the same bar of the window appears reflected from the second plane of the crystal corresponding with plane *b* (Figs. 377 and 378), and until it appears to touch the line below; and having, in adjusting the *first* plane, turned the pin GH *on its axis*, to bring the reflected image of the bar of the window to coincide accurately with the line below, *now move the lower end of the pin laterally*, either towards or from the instrument, in order to make the image of the same bar, reflected from the second plane, coincide with the same line below.

"Having ascertained by repeatedly looking at, and adjusting both planes, that the image of the horizontal bar, reflected successively from each plane, coincides with the observed lower line, the crystal may be considered ready for measurement.

"Let the 180° on the graduated circle be now brought opposite the 0 of the vernier at L, by turning the handle, M; and while the circle is retained accurately in this position, bring the reflected image of the bar from the *first* plane to coincide with the line below, by turning the *small* circular handle, S. Now turn the graduated circle, by means of the handle, M, until the image of the bar, reflected from the *second* plane, is also observed to coincide with the same line below. In this state of the instrument the vernier at L will indicate the degrees and minutes at which the two planes are inclined to each other.

"The accuracy of the measurements taken with this instrument will depend upon the precision with which the image of the bar, reflected successively from both planes, is made to appear to coincide with the same line below; and also upon the 0, or the 180°, on the graduated circle, being made to stand precisely even with the lower line of the vernier, when the first plane of the crystal is adjusted for measurement. A wire being placed horizontally between two upper bars of the window, and a black line of the same thickness being drawn parallel to it below the window, will contribute to the exactness of the measurement, by being used instead of the bar of the window and any other line.

"Persons beginning to use this instrument are recommended to apply it first to the measurement of fragments at least as large as that represented in Fig. 381, and of some substance whose planes are bright. Crystals of carbonate of lime will supply good fragments for this purpose, if they are merely broken by a slight blow of a small hammer.

"For accurate measurement, however, the fragments ought not, when the planes are bright, to exceed the size of that shown in Fig. 380, and they ought to be so placed on the instrument, that a line passing through its axis should also pass through the centre of the small minute fragment which is to be measured. This position on the instrument ought also to be attended to when the fragments of crystal are large. In which case the common edge of the two planes, whose inclination is required, should be brought very nearly to coincide with the axis of the goniometer; and it is frequently useful to blacken the whole of the planes to be measured, except a narrow stripe on each close to the edge over which the measurement is to be taken."

MINERALOGY.

The science which enables us to classify and arrange those inorganic productions of nature which are called minerals, and enables us to identify or distinguish them from one another, is termed *mineralogy.*

Mineral.—By the word mineral we understand all substances found in nature, which are homogeneous or of the same composition throughout their structure, and do not owe their origin to the action of animal or vegetable life. This definition excludes all rocks which are variable in their character and composition, as well as all substances, such as coal, which are products of vegetable life. Some of these are retained in most descriptions of minerals though they do not strictly belong to the subject of mineralogy.

Species of Minerals.—The various members of the mineral kingdom which essentially differ from one another are divided into *kinds* or *species.* By far the majority of mineral substances are found to assume definite mathematical forms, bounded, for the most part, by plane surfaces and straight lines—these are called *crystals.* The subject of crystallography we have already discussed at some length, particularly in its relation to minerals. Generally speaking, substances which differ in chemical composition from other substances constitute distinct mineral species; again, substances which agree in chemical constitution, but differ in the character of their crystalline forms, are divided into separate mineralogical species. Thus native gold, silver, and copper, which have the same crystalline forms, but differ in chemical composition, give three distinct species of minerals. Calcite and aragonite,—which have the same chemical composition, being both carbonate of lime, but present different kinds of crystalline forms, one series belonging to the rhomboidal and the other to the prismatic system,—constitute two distinct species. Difference in chemical composition, independently of crystalline form, or difference in the class of crystalline form, while the chemical composition remains the same, principally determine the division of minerals into species. This rule does not hold true universally, for some bodies admit of considerable change in their chemical composition without affecting their form and many other properties—several classes of such substances, of which the *garnets* and *alums* may be taken as an illustration, have by the common consent of mineralogists been considered as similar species, though differing from one another in chemical composition.

Characteristics of Minerals.—The crystalline form and chemical constitution of minerals are the principal characteristics by which, when known, their species and names may be discovered. Though these, in general, are sufficient for the identification of a mineral; yet, when the crystalline form is not apparent, or the chemical constitution determined without great trouble, there are many other characteristics which will enable us to describe and identify the species. The chief of these are the hardness, specific gravity, fracture, lustre, colour, brittleness, flexibility, malleability, taste, smell, and other natural properties of the substance. Sometimes the optical and electrical properties afford assistance.

Crystalline Form.—This subject has already been discussed at such considerable length, that it is unnecessary to say anything more here than to quote from Dana that, " To learn to distinguish minerals by their colour, weight, and lustre, is so far very well; but the accomplishment is of a low degree of merit, and when most perfect makes but a poor mineralogist. But when the science is viewed in the light of chemistry and crystallography, it becomes a branch of knowledge perfect in itself, and surprisingly beautiful in its exhibitions of truth. We are no longer dealing with pebbles of pretty shapes and tints, but with objects modelled by a divine hand, and every additional fact becomes to the mind a new revelation of His wisdom."

Chemical Composition.—There are sixty-two or sixty-three elementary bodies known (See CHEMISTRY, page 29); all species of minerals are formed by some one of these elements, or else result from their combinations. The following is a list of their symbols and chemical equivalents :—

Ag, Argentum (silver)	1349·01	Na, Natrium (sodium)	287·17
Al, Aluminium	170·42	Ni, Nickel	369·14
As, Arsenic	936·48	Nb, Niobium	
Au, Aurum (gold)	2456·72	N, Nitrogen	175·25
Ba, Barium	854·85	Nr, Norium	
Bi, Bismuth	2660·75	Os, Osmium	1242·60
B, Boran	136·31	O, Oxygen	100·00
Br, Bromine	999·63	Pb, Plumbum (lead)	1294·50
Cd, Cadmium	696·77	Pd, Palladium	662·54
Ca, Calcium	250·00	Pl, Pelopium	
C, Carbon	75·00	P, Phosphorus	391·55
Ce, Cerium	590·80	Pt, Platinum	1233 50
Cl, Chlorine	443·20	R, Rhodium	652·00
Cr, Chrome	349·83	Rt, Ruthenium	
Co, Cobalt	368·44	Se, Selenium	495·30
Cu, Cuprum (copper)	396·00	Si, Silicon	184·88
D, Didymium	620·00	Sr, Strontium	545·60
Do, Donorium		S, Sulphur	200·00
E, Erbium		Sb. Stibium (antimony)	1612·90
Fe, Ferrum (iron)	350·06	Sn, Stannium (tin)	735·30
F, Fluorine	235·71	Ta, Tantalum	1148·40
G, Glucinium	58·08	Te, Tellurium	801·80
H, Hydrogen	12·50	Tr, Terbium	
Hg, Hydrargyrum (mercury)	1250·80	Th, Thorium	743·90
I, Iodine	1385·57	Ti, Titanium	301·60
Ir, Iridium	1232·00	U, Uranium	742·90
K, Kalium (potassium)	488·94	Va, Vanadium	856·90
La, Lanthanium	588·00	W, Wolfram (scheelium)	1188·40
L, Lithium	81·85	Y, Yttrium	402·50
Mg, Magnesium	157·75	Zn. Zinc	406·60
Mn, Manganese	344·44	Zr, Zirconium	281·20
Mo, Molybdenum	596·10		

The letters or symbols placed before these elementary bodies enable us to express with great conciseness the chemical composition of any mineral, and the numbers which follow them, to determine the comparative weights of its component elements.

Thus, ZnO represents the red oxide of zinc, spartalite, consisting of one equivalent of zinc and one of oxygen.

FeS^2, iron pyrites consisting of one equivalent of iron and two equivalents of *sulphur.*

Fe^2O^3 the red oxide of iron or hematite, consisting of two equivalents of iron and three of oxygen.

AsO^5, arsenic acid, consisting of one equivalent of arsenic and five equivalents of oxygen.

HO, water consisting of one equivalent of hydrogen and one of water.

Pharmacosiderite, an arseniate of iron, is represented by the more complex symbol $3Fe^2O^3 + 2AsO^5 + 12HO$, showing that it consists of 3 equivalents of red oxide of iron, 2 of arsenic acid, and 12 of water. The following formulæ will show the relative weights of the constituents of the above substances.

Spartalite.				Iron Pyrites.			
Zn = 1 equiv. of Zinc	= 406·60 or	80·26		Fe = 1 equiv. of Iron	= 350·00 or	46·67	
O = 1 „ Oxygen	= 100.00	19·74		S^2 = 2 „ Sulphur	= 400·00	53·30	
ZnO = 1 „ Spartalite	= 506·60	100·00		FeS^2 = 1 „ Iron Pyrites	= 750·00	100·00	

The first column is obtained by multiplying the equivalent number of the elements by the number of its equivalents in the substance, and shows that 506·60 parts by weight of spartalite contain 406·60 parts of zinc and 100 parts of oxygen, or that 750 parts of iron pyrites contain 350 parts of iron and 400 of sulphur.

The second column shows that 100 parts by weight of spartalite contain 80·26 parts of zinc and 19·74 of oxygen; and 100 parts of iron pyrites contain 46·67 of iron and 53·30 of sulphur. This column is found by multiplying the number for the zinc, oxygen, iron, or sulphur of the first column by 100 and dividing it by the equivalent number for the substance, thus,

$$\frac{406{\cdot}60 \times 100}{506{\cdot}60} = 80{\cdot}26 \quad \frac{100{\cdot}00 \times 100}{506{\cdot}60} = 19{\cdot}74 \quad \frac{350 \times 100}{750} = 46{\cdot}67 \quad \frac{400 \times 100}{750} = 53{\cdot}30$$

To determine the relative weights of the constituents of pharmacosiderite we have the following calculations:—

Fe^2 = 700·00	As = 936·48	H = 12·50
O^3 = 300·00	O^5 = 500·00	O = 100·00
Fe^2O^3 = 1000·00	AsO^5 = 1436·48	HO = 112·50
3	2	12
$3Fe^2O^3$ = 3000·00	$2AsO^5$ = 3972·96	12HO = 1350·00

$3Fe^2O^3$ =	3 equivalents of the	Red oxide of Iron	= 3000·00 or	41·53
$2AsO^5$ =	2 „ „	Arsenic acid	= 3972·96	39·78
12HO =	12 „ „	Water	= 1350·00	18·69
	1 „ „	Pharmacosiderite	= 8322·96	100·00

There are two methods of investigating the chemical composition of a mineral—the qualitative and the quantitative. The qualitative analysis determines the nature of the constituents, and the quantitative their relative proportions. For the method of conducting these analyses we must refer the student to the science of chemistry, contenting ourselves with expressing the chemical composition of the mineral in symbols, according to the best authorities, and indicating after the letter B whether they are fusible or not before the blowpipe, and also whether they are soluble or insoluble in acids.

Hardness.—The comparative hardness of minerals is of great assistance in determining their species, and it is a matter of great regret that this important property has not been more accurately observed. The following scale introduced by Mohs is that generally adopted for indicating the hardness of minerals :—

1. TALC.	3. CALCITE.	5. APATITE.	7. QUARTZ.	9. CORUNDUM.
2. ROCK SALT.	4. FLUOR.	6. FELSPAR.	8. TOPAZ.	10. DIAMOND.

The specimens of the above minerals used for testing the hardness of other minerals are generally fragments of transparent or cleavable varieties.

The hardness of talc is said to be 1, of rock salt 2, of calcite 3, and so on. A mineral which neither scratches nor is scratched by any member of the series is said to be of the same hardness. Thus, a mineral which neither scratches nor is scratched by quartz is said to be of the hardness of 7, generally indicated thus, H 7. A mineral which scratches calcite, and is scratched by fluor, is said to be of a degree of hardness between 3 and 4, which is indicated by 3·25, 3·5, or 3·75, according as it is regarded as $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ harder than calcite, No. 3. To ascertain these fractional degrees of hardness the three minerals are passed successively over a finely-cut hard steel file, one end of the file being held by the hand, while the other rests on a table. The degree of hardness of the intermediate substance is determined by observing the degree of resistance it affords to the file, the quantity of powder left on its surface, and the sound produced by the operation. Care must be taken to use specimens nearly of the same form and size, and also of great purity.

Streak.—This is a property examined by scratching the mineral by a substance harder than itself, or when it is not too hard, by rubbing it on a piece of unglazed porcelain. A writing diamond will scratch all other minerals; but a fragment of corundum, quartz, or a hard steel point, will be sufficient for most. The scratch may be a rough or smooth line, and it may be accompanied by the powder of the mineral.

The colour of this powder determines the colour of the streak, and it is distinguished as shining or dull, according as the scratch is of a greater or less lustre than the surface of the mineral scratched.

Specific Gravity.—Equal volumes of different substances are frequently found to differ in their weights. To determine the relative weights, or the specific gravity of equal volumes of substances, distilled water at a temperature of 60° of Fahrenheit, or 15·55° centrigrade, is taken as the standard unit of comparison. As it would be extremely difficult to obtain equal volumes of the substances whose specific gravity is required, advantage is taken of the hydrostatical property, that a body immersed in water displaces a mass of water equal in volume to itself, and has its weight diminished by that of the equal volume of water it displaces. The *specific gravity* of a body being the ratio of its weight to an equal volume of distilled water at the temperature of 60° Fah., all we have to do to determine it, is to weigh the substances first in air, and then in distilled water at 60° Fah. For this purpose the *hydrostatic balance* (Fig. 382) is made use of.

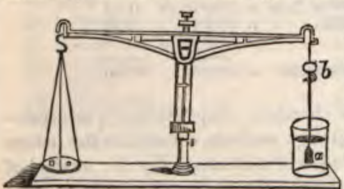


Fig. 382.

The hydrostatic balance is an ordinary balance, the scale pan of which is removed from one side, and replaced by a counterpoise *b*, which balances the other scale pan; under *b* is placed a hook, to which the substance to be weighed is suspended by a fine fibre or platinum wire. For accurate experiments the balance should be sufficiently delicate to weigh to the one-hundredth part of a grain. Let A be the weight of the substance in air, W its apparent weight when suspended in water, and S G its specific gravity—then:

$$S\,G = \frac{A}{A - W}$$

When great accuracy is required, it may be necessary to take into account the weight of the mass of air displaced by the body when weighed in air. Since water is 815 times heavier than air, we must subtract from the specific gravity obtained above—

$$\frac{W}{815\,(A - W)}$$

Thus in a specimen of cordierite, whose weight in air is 311·91 grains, weight in water 195·46 grains.

$$\text{Here } S\,G = \frac{311{\cdot}91}{311{\cdot}91 - 195{\cdot}46} = 2{\cdot}678$$

If we take into account the weight of the air displaced when it is weighed in air, we must deduct from the above—

$$\frac{195{\cdot}46}{815 \times (311{\cdot}91 - 195{\cdot}46)} = {\cdot}002$$

which makes the corrected specific gravity 2·676. The bubbles of air which attach themselves to the surface of the mineral when suspended in water, are removed by boiling the water in which it is suspended briskly for some minutes, the whole being left to cool down to the temperature of 60° Fah.

If the mineral be so light as to float on the water, a sinker of brass, or some other substance whose apparent weight when suspended by itself in the distilled water is B, is attached to it, so as to cause it to sink.

Let A be the weight of the light mineral, B that of the sinker suspended by itself in the distilled water, C the weight of A and B when suspended in the water together; then in this case

$$S\,G = \frac{A}{A + B - C}$$

Thus, to find the specific gravity of a substance which weighs 20 grains in air, it is sunk by a weight which weighs 87·22 grains when immersed by itself in water; the two substances being suspended in the water together, weigh 23·89 grains. In this case

$$S\,G = \frac{20}{20 + 87{\cdot}22 - 23{\cdot}89} = \frac{20}{83{\cdot}33} = {\cdot}240$$

If the mineral can only be obtained in small fragments, or if it be supposed to contain vacuities it must be reduced to fine powder, and the specific gravity bottle (Fig. 383) made use of. This instrument is equally applicable for the determination of the specific gravity of solids or fluids. It consists of a thin glass bottle of a globular shape, and is generally made to contain either 500 or 1,000 grains of distilled water at 60° Fah. It is furnished with a ground glass stopper which is pierced through the centre with a straight hole of very fine bore. The object of this is, that when the bottle is filled up to the neck with water or any other liquid, the stopper may be inserted, and, the excess of liquid escaping through the hole in the stopper, the bottle may be filled with a definite volume of liquid. Suppose our object is to find the specific gravity of a liquid, and that we use a 1,000 grain bottle, we proceed as follows:—Having placed the empty bottle in one pan of a balance, we counterpoise it by a weight in the other; we then fill the bottle with the liquid at 60° Fah. in the way described, wipe it dry, replace it in the scales and restore the equilibrium by adding more weights. The weight added is evidently that of the liquid, but as the same volume of water at 60° weighs 1,000 grs., if the bottle be accurately made, the specific gravity of the liquid is equal to its weight expressed in grains divided by 1,000. As the bottles are seldom made with such accuracy as to contain exactly the right quantity of water, let W be the weight of bottle full of air, W′ its weight filled with distilled water at 60° Fah., then making an allowance for the weight of the air contained in the bottle, the weight of the water contained in the bottle will be

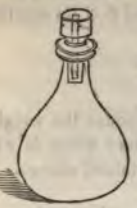


Fig. 383.

$$\frac{815(W - W')}{814}$$

and the weight of the bottle will be the difference between this quantity and W′. A piece of lead equal to this must be cut and kept as a counterpoise for the bottle. If a bottle, which has thus been found to contain 500·72 grains of water, be counterpoised by a piece of lead, and filled with sea water weighs 516·86 grains, the specific gravity of the sea water will be $\frac{516 \cdot 86}{500 \cdot 72}$ or 1·032.

To determine the specific gravity of a powdered mineral, a known weight M of the substance is introduced into the specific gravity bottle, which is then carefully filled with water and weighed.

Let M be the weight of the mineral introduced.
M′ the weight of the water it displaces in the bottle.
w the weight of the water which the bottle would contain when full.
W the weight of the bottle filled with the mineral and water, the lead counterpoise for the weight of the bottle itself being in the opposite scale.

Then the specific gravity of the substance $= \frac{M}{M'}$

and $W = w + M - M'$, or, $M' = w + M - W$

and therefore $SG = \frac{M}{w + M - W}$.

Let 86·02 grains of a mineral be introduced into a bottle formed to contain 500·72 grains of water, and the bottle filled with distilled water, let it then weigh 554·74 grains.

Then $SG = \frac{86 \cdot 02}{500 \cdot 72 + 86 \cdot 02 - 554 \cdot 74} = 2 \cdot 688$.

Nicholson's Areometer.—A cheap and convenient substitute for the balance is found in a little instrument represented in Fig. 384, and called *Nicholson's Areometer*, which we will briefly describe. V is a metallic ball or float having a descending hook, to which is hung a little weighted pan *l* to hold the substance which is weighed in water; the wire stem *f* supports a cup c. A mark t, on the stem, shows the point at which the whole apparatus will float in a tall vessel of water, when a certain known weight (called the balance-weight) is put in the cup *e*. The specimen under examination must not exceed in weight the balance-weight, this being the limit of the instrument. Suppose the limit to be 100 grains. To find by this instrument the specific gravity of a substance, place it on *e*, and add weights till the instrument sinks to the mark *t*, the added weight being subtracted from 100, gives the weight of the specimen in air. Now place the specimen in the pan *l*, and again add weights to *e*. As much more weight on *e* will now be required as corresponds to the weight of a bulk of water equal to the specimen, which, it must be remembered, is buoyed up by a power just equal to such weight. The difference of weight thus found will be the divisor of the weight of the specimen, and the quotient will be the specific gravity sought.

Fig. 384.

This instrument is generally made of brass or tin-plate, but may be more elegantly made of glass.

For example, put the specimen in balance-weight = ...	100·00
Weights added to sink instrument to *t* = ...	22·57 grs.
Weight of specimen in air = ...	77·43
Specimen placed in lower pan requires additional weights =	35·43

35·43 — 22·57 = 12·86, the weight of a like bulk of water; then $\frac{77{\cdot}43}{21{\cdot}86} = 6{\cdot}02$, the specific gravity sought.

When the specific gravity of two substances are known, by taking the specific gravity of their compound, we may find the relative weights of the two components. Thus, knowing the weight of a nugget of quartz and gold, by means of its specific gravity we can determine the weight of the gold contained in it.

Let G be the weight of gold in a nugget. g its specific gravity.
Q the weight of the quartz in a nugget. q its specific gravity.
N the weight of the nugget. n its specific gravity.

then
$$G + Q = N$$
and
$$\frac{G}{g} + \frac{Q}{q} = \frac{N}{n}$$
From which equations we may obtain the following,
$$G = N.\ \frac{(n - q)\,g}{(g - q)\,n}$$

Thus, if the specific gravity of a nugget whose weight is $11\frac{1}{2}$ oz. be 7·43, considering the specific gravity of the quartz as 2·62 and that of fine gold as 19·35, we shall have from the above formula

$$G = 11{\cdot}5\ \frac{7{\cdot}43 - 2{\cdot}62}{19{\cdot}35 - 2{\cdot}62} \times \frac{19{\cdot}35}{7{\cdot}43} = \frac{10703452{\cdot}5}{1243039} = 8{\cdot}6107$$

or the amount of fine gold in the nugget will be about 8·6107 ounces.

The asperities on the surface of the quartz, as well as the cavities it contains, causes the nugget to displace more water than it should; consequently the amount of gold is rather understated. (Galbraith and Haughton's "Manual of Hydrostatics.")

Double Refraction and Polarized Light.—If a ray of light fall obliquely on a plate of glass or any other transparent medium, its direction is changed as it passes into the substance, and it is bent or refracted according to a law, known as the law of sines. There are certain transparent substances which possess the power of splitting the refracted ray into two, one of which mostly follows the ordinary law of refraction, which belongs to transparent substances, and the other a more complicated law. Such substances are said to possess the power of double refraction. Calcite possesses this property in so high a degree, that all objects seen through it appear double. This is most strikingly observed in the very transparent varieties called Iceland spar.

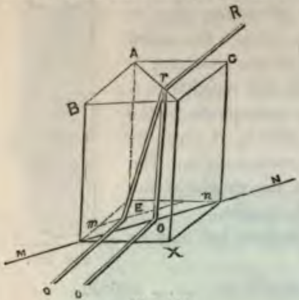


Fig. 385.

If a ray of light R r fall obliquely on any one of the surfaces of a cleavage rhomboid of calcite (Fig. 385),it will be divided on entering into the crystal into two rays, one r O in the same plane as the ray R r, following the ordinary law of refraction, and therefore called the ordinary ray; and the other, r E, following a more complicated law, and called the extraordinary ray. If the rhomboid be placed on a piece of paper having a black dot, the dot seen through the crystal will appear double, and one image of the dot will seem to be above the other; and in whatever position the rhomboid is placed, an imaginary line joining the two dots will always be parallel to the axis, P_1 P_2, which joins the two three-faced solid angles, P_1 and P_2, of the rhomboid (Fig. 386), formed by three equal and similar oblique angles. A line or printed characters viewed through the rhomboid will appear double; the distance between the two images will depend on the thickness of the rhomboid, being greater as the rhomboid is thicker.

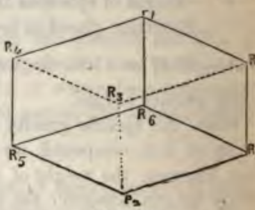


Fig. 386.

If the solid angles, P_1 and P_2, of the rhomboid be ground down and replaced by two triangular surfaces, as in Fig. 387, perpendicular to the axis, P_1 P_2, and these surfaces be polished, it will be found that a ray passing directly through these triangular surfaces will not suffer double refraction; and any object viewed through these planes will appear single. The axis, P_1 P_2, parallel to which there is no double refraction, is called the *optic axis* of the crystal. All transparent crystals, with the exception of those belonging to the cubical system, possess the property of double refraction, though few so powerfully as to cause objects seen through them to appear double.

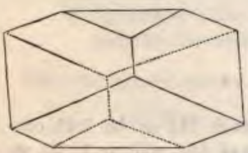


Fig. 387.

Nitrate of soda possesses the same crystalline form, cleavage, and the property of double refraction in the same degree of energy as calcite, and may be substituted for it in experiments on these optical peculiarities.

The light which passes through a doubly-refracting crystal suffers a peculiar change, which is called *polarization*. A ray of light which has been once split by passing through a doubly-refracting substance, will not be divided again on passing through another doubly-refracting surface, and there is a certain angle for every substance which is not metallic, and is capable of reflecting ordinary light, at which the ray of light which has suffered double refraction cannot be reflected. A ray of light which has acquired these two properties, is called *polarized light.* Light may be polarized not only by passing through a doubly-refracting substance, but also by being reflected at a particular angle by a non-metallic reflector, or by being refracted at a particular angle through parallel plates of a transparent substance, which does not possess the property of double-refraction.

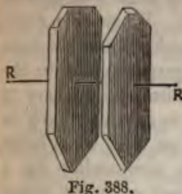


Fig. 388.

Fig. 389.

Tourmaline, especially the green and brown transparent varieties, can be so prepared as to polarize light. If a crystal of tourmaline be cut into plates, parallel to any one of the faces of the hexagonal prism, or to the principal or optic axis of the crystal, ordinary light on passing through the plate of tourmaline will be doubly refracted; but one of the two rays into which the ray is split will be completely absorbed by the tourmaline, if the plate be thick enough, and the other will be transmitted. If we look through the plates of tourmaline in the position of Fig. 388. as they are cut from the crystal, we can see through them; but if they be placed across each other, as in Fig. 389, we shall not be able to see through them, where the planes of the two plates are placed in contact with each other.

If we cause one plate of tourmaline to revolve on the other, in its own plane, through an angle of 360°, we shall find that there are two positions in which it is incapable of transmitting polarized light. A bundle of plates of glass, consisting of eight or ten similar pieces, with their edges united together with sealing-wax, or any other means, held in such a manner as to cause the light to pass through the plates obliquely, as in Fig. 390, may be substituted for the plate of tourmaline. There is also an instrument called Nicol's prism, consisting of two prisms of Iceland spar, united together with Canada balsam, at such an angle as to allow only one of the two rays of the doubly-refracted light to pass through the prism. The Nicols' prism and the plates of glass, have this advantage over the plates of tourmaline, that the light which is polarized by passing through them is not coloured.

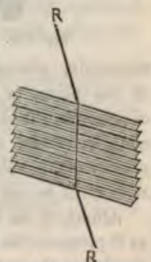


Fig. 390.

If a ray of light, which has been polarized, pass through a doubly refracting crystal, it becomes depolarized, or recovers its property of being reflecting at all angles by a non-metallic reflector, and of passing through the plate of tourmaline, the bundle of glass, or the Nicol's prism, in every position in which they may be held.

This property affords a ready test of double refraction,—if a plate, with parallel surfaces, be cleared or cut from any doubly-refracting crystal and placed between the two plates of the tourmaline, in the position, Fig. 389, in which they lose their transparency, the transparency will be restored; and if the plate be of a certain degree of thinness, depending upon the substance of which it is composed, it will appear coloured. The plate of tourmaline, through which the light in passing is polarized, is called the *polarizer*, the doubly-refracting plate the *depolarizer*, and the other plate of tourmaline through which it is seen the *analyzer*. Any non-metallic reflector, a plate of tourmaline, a bundle of glass plates, or the Nicol's prism, may be used as the *polarizer* or as the *analyzer*. Any instrument arranged with any combination of any two of these for the analyzer and polarizer, for the purpose of observing these phenomena, is called a polariscope.

The most convenient analyzer is a polished mahogany table or a sheet of glass lying on the table, reflecting the light of the sky falling on it through a window. If a thin plate of mica or selenite, held in the hand with its plane perpendicular to that of the table, be viewed through a plate of Tourmaline, a bundle of glass held obliquely, or a Nicol's prism, by advancing or retiring from the table its polarizing angle will soon be discovered by the brilliant tints assumed by the mica or selenite. When this angle has been determined,—if we substitute for the plate of mica a thicker slice cut from any transparent crystal belonging to the rhombohedral system, perpendicular to the principal or optic axis, or to any of the faces of the hexagonal prism, taking care to hold the slice close to the analyzer,—as we cause the analyzer to revolve round its axis we shall see a black cross, surrounded by a brilliant series of rings, exhibiting all the colours of the spectrum, as in Fig. 391, succeeded by another series of rings, intersected by a transparent cross (Fig. 392). The cleavage rhomb of calcite, or that of nitrate of soda, prepared as in Fig. 387, and viewed through the two triangular planes, will exhibit these phenomena with great brilliancy, if the thickness of the plate, or the distance between the triangular planes, be from a quarter to an eighth of an inch. The intervals between the rings are smaller as the thickness of the slice increases, or, the thickness of the slice being the same, as the doubly refracting energy of the substance from which it is cut. In crystals of the *pyramidal system,* the slice must be cut parallel to the basal pinacoids of the crystal.

Fig. 391.

Fig. 392.

Quartz is an exception to other substances belonging to the rhombohedral system as it presents the phenomena of circular polarization. The slice of quartz, cut perpendicular to the optic axis or any of the planes of the hexagonal prism, presents in every position of the analyzer the rings without the cross, the centre of the inner ring being of one colour, which passes through all the varieties of the spectrum as the analyzer is rotated on its axis. In some specimens the colours succeed in their order from red to violet, as the analyzer is moved from right to left, and in others when it is moved from left to right.

Slices cut in proper directions from translucent crystals belonging to the *prismatic, oblique,* and *anorthic* systems, all of which have two axes of doubled refraction, when

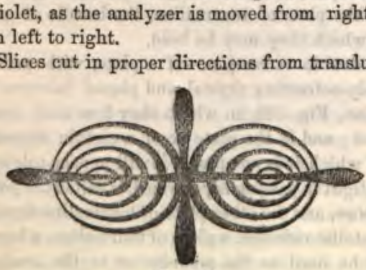


Fig. 393.

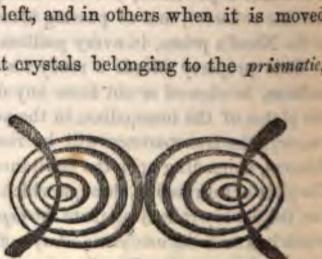


Fig. 394.

viewed as above, present a double system of rings round each axis; when the axes are sufficiently near to be observed at once, as in the case of nitrate of potash, the analyzer being held in the position in which it would show the black cross in the preceding case, Figs. 393 and 394 will be seen, consisting of two series of oval-coloured rings, intersected by dark brushes, which will change from the position, Fig. 393, to that in Fig. 394, as the slice of the crystal is made to rotate round its axis, while the analyzer is held fixed. If the slice of the crystal be fixed while the analyzer is made to revolve, the dark brushes will alternately vanish and re-appear, as in the crystals with one optic axis.

Arrangement and Description of Minerals.—Most modern works on Mineralogy having followed a chemical arrangement of minerals, we shall adopt that of Berzelius, as modified in the collection in the British Museum. The British Museum contains probably the finest collection of minerals in the world; it is public property, and easy of access to every student; we shall, therefore, in our description of each mineral indicate the number of the case in which it may be found. For the sake of distinguishing the specimens of one mineral from those of another, in the British Museum, the name of each mineral in the case is printed on a label with a border coloured red, green, blue, or yellow; a thin slip of wood, of the same colour as the border, surrounds all the specimens of the mineral indicated by the name on the label. Some idea of the value of the collection in the British Museum may be formed from the fact that it cost government more than £30,000, and has been greatly enriched by many valuable contributions presented to it, especially the rich private collection of the Rev. Mr. Cracherode.

In describing each mineral we shall give its name and synonymes, chemical composition in symbols, crystalline system, hardness, and specific gravity, indicated by the letters H and G; case in the British Museum; fracture, transparency, or opacity; lustre, colour, streak; brittleness, or other remarkable property; fusibility or infusibility before the blowpipe; the manner in which it is affected by acids, followed by some of its principal localities, and any observations which may be necessary as to its uses and properties.

Iron.—*Native Iron.*—Fe. **cubic.** H = 4·5 G 7·0 . . . 7·8. Case 1. Soluble in hydrochloric acid. B. infusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* pale steel-gray. *Str.* the same.

Native iron of terrestrial origin is mixed with a small portion of other metals, but without nickel. Dauphine, Auvergne, Brazils, Yates, United States. *Meteoric iron: Ærolite, Meteorite.*—Found in meteoric stones, with nickel, cobalt, and other metals. Siberia, Peru, Mexico, North America, Cape of Good Hope, several parts of Europe. Meteoric iron forms the substance of the rough-shaped knives of some of the Esquimaux tribes of North America. Iron is most extensively used in the arts and manufactures.

Copper.—*Native Copper.*—Cu. **cubic.** H 2·5 . . . 3·0 G 8·5 . . . 8·9. Case 1 Soluble in nitric acid. B. easily fusible. *Frac.* hackly. *Lus.* metallic. *Col.* red. *Str.* shining.

Found in veins and beds. Disseminated through rocks of all formations. Hungary, Siberia, Cornwall, Waterford, Mansfield, Kaursdorf, Chessy, Spain, Fahlun, North America, Cuba, Brazils, China, Japan, Nassau, Saxony. Copper, either by itself, or else in combination with other metals, is extensively used in the arts and manufactures. Copper is used for the stamping machinery of powder-mills, because it does not emit sparks.

Bismuth.—*Native Bismuth.*—Bi. **rhombohedral.** H 2·0 . . . 2·5 G 9·6 . . . 9·8. Case 1. Soluble in nitric acid. B. easily fusible. *Frac.* indistinct. Opaque. *Lus.* metallic. *Col.* reddish-silver-white.

Found in veins, in granite, gneiss, mica slate, and transition rocks. Saxony, Thuringia, Bohemia, Norway, Sweden, the Pyrenees, Connecticut, Cornwall. Bismuth enters into several alloys used in the arts, such as pewter, solder, and type metal.

Lead.—*Native Lead.*—Pb. **cubic.** H 1·5 G = 11·35. Case 1. Soluble in nitric acid. B. easily fusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* shining.

Said to be found in lava and carboniferous limestone. Madeira; Bristol; Kenmare Ireland; Alston, Cumberland. Used extensively in the arts and manufactures.

Silver.—*Native Silver.*—Ag. **cubic.** H 2·5 — 3·0 G 10·1 — 11·0. Case 2. Soluble in nitric acid. B. easily fusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* white. *Str.* shining.

Found in veins, rarely in beds; in crystalline slate rocks, gneiss, mica slate, hornblende slate, granite, syenite, porphyry. Norway, Sweden, Saxony, Bohemia, Hungary, Transylvania, Siberia, the Hartz, Baden, the Tyrol, France, Peru, Mexico, Chili, Cornwall, Alva, Scotland. Used extensively in the arts and manufactures; mixed with copper in the proportion of 12½ to 1, it forms the standard silver of British coinage.

Mercury.—*Native Mercury.*—Hg. **cubic.** H·0· G 13·6. Case 2. Soluble in nitric acid. B. volatilizes. Opaque. *Lus.* bright metallic. *Col.* tin-white.

Found in cavities or crevices of rock containing cinnabar. Carniola, Spain, Bohemia, the Palatinate, the Tyrol, Carinthia, Peru, China, the Hartz.

Amalgam.—*Hydrarguret of Silver.*—Ag. Hg. **cubic.** H 3·0 — 3·5 G 13·7 — 14·1 Soluble in nitric acid. B. volatilizes. *Frac.* conchoidal. Opaque. *Lus.* bright metallic. *Col.* silver-white. *Str.* the same.

Found in beds containing mercury and cinnabar. The Palatinate, Hungary, Spain, France, Sweden. That found in the Arquero mine, in Chili, has been called *Arquerite.* Extensively used in the arts and for philosophical apparatus, and in the manufacture of chemical and pharmaceutical preparations.

Palladium.—*Native Palladium.* Pd. **cubic.** H 4·5 — 5·0 G 11·8 — 12·14. Case 2. Soluble in nitric acid. B. infusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* light steel gray.

Occurs in rolled grains with platina, and particles imbedded in and combined with gold. Brazils, Tilkerode in the Hartz. Does not tarnish. Has been used in the manufacture of philosophical instruments, particularly balances.

Platinum.—*Native Platina.*—Pt. **cubic.** H 4·0 — 4·5 G 17·3 — 18·94. Case 2. Soluble only in nitro-muriatic acid. B. infusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* steel gray. *Str.* the same, bright. Ductile.

Found with gold in veins of quartz, in syenite, and in alluvial sand. The Ural, Brazils, St. Domingo, Borneo, the Rhone, North Carolina. Of great value in the construction of philosophical and chemical apparatus. It is used in painting on porcelain.

Osmiridium.—*Alloy of Iridium and Osmium.*—Ir. Os. **rhombohedral.** H 7·0 G 19·3 — 21·2. Case 2. Insoluble in acids. B. infusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* tin-white and lead-gray. *Str.* the same.

Occurs in isolated crystals and grains with gold and platinum. South America, the Ural, Borneo.

Iridium.—*Alloy of Iridium and Platinum.* Ir. Pt. **cubic.** H 6·0 — 7·0 G 22·65 — 22·80. Insoluble in acids. B. infusible. Opaque. *Lus.* metallic. *Col.* silver-white. Highly ductile.

Occurs with platinum and osmi-iridium. The Ural, Ava. Harder, heavier, and paler in colour than platinum.

Gold.—*Native Gold.*—Au. **cubic.** H 2·5 — 3·0 G 14·55 — 19·1. Case 3. Soluble in nitro-muriatic acid. B. fusible. *Frac.* hackly. Opaque. *Lus.* metallic. *Col.* gold yellow. *Str.* bright. Ductile and malleable.

Occurs in felspathic and hornblende rocks, in conglomerates, in alluvial deposits and sands of rivers, in veins of greenstone and syenitic porphyry, in veins of quartz, in seleniuret of lead; generally combined with silver—when the proportion is considerable, it is called Electrum. Hungary, Transylvania, Mexico, Peru, and New Spain; California, Brazils, North Carolina, Australia, St. Domingo, Bohemia, Africa, Thibet, China, Java, Borneo, Sumatra, the Hartz, Danube, Rhine, Wicklow, Perthshire, Cornwall. The most ductile and flexible of all metals; extensively used for coinage, articles of luxury, and in the arts.

Tellurium.—*Native Tellurium.*—Te. **rhombohedral.** Case 3. H 2·0 — 2·5 G 6·1 — 6·3. Soluble in nitric acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* tin-white. *Str.* the same.

Occurs in a sandstone rock. Faceby, Transylvania.

Tetradymite.—*Tellurwismuth, Bornine, Molybdena-silver, Sulpho-telluret of Bismuth.* **Rhombohedral.** Case 3. H 1·0 — 1·5 G 7·4 — 7·5. Soluble in nitric acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* bright steel-gray. *Str.* the same.

Occurs in conglomerate. Schoubkan in Hungary, Deutsch Pilsen, near Grard.

Petzite.—*Hessite, Tellur Silber, Telluret of Silver.*—Ag. Te. **cubic.** Case 3. H 2·5 . . . 3·0 G 8·31 — 8·83. Soluble in hot nitric acid. B. volatilizes. *Frac.* even. Opaque. *Lus.* metallic. *Col.* steel-gray. *Str.* the same. Malleable.

Occurs with iron and copper pyrites in talk-slate. Siberia, Transylvania.

Nagyagite.—*Black or Foliated Tellurium. Auro-plumbiferous telluret.*—Pb. Te. Au. **pyramidal.** Case 3. H 1·0 — 1·8 G 7.0 — 7·2. Soluble in nitric acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* the same.

Occurs in veins with quartz. Nagyag and Offenbanya, Transylvania. Prized for the gold it contains.

Altaite.—*Telluret of Lead.*—Pb. Te. **cubic,** H 3·0 – 3·5 G 8·15. Soluble in nitric acid. B. fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* tin-white. *Str.* the same.

Found with petzite in Sawodinski mine, in the Altai.

Sylvanite.—*Graphic and Yellow Tellurium, Schrift-erz, Mullerine.*—Te. Pb. Au. **prismatic.** Case 3. H 1·5 – 2·0 G 7·99 — 8·33. Soluble in nitric acid. B. fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* steel-gray. *Str.* the same.

Found in porphyry. Offenbanya and Nagyag, Transylvania. A very rare mineral.

Antimony.—*Native Antimony.*—Sb. **rhombohedral.** H 3·0 — 3·5 G 6·6 — 6·7. Case 3. Soluble in nitro-muriatic acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* tin-white. *Str.* the same.

Occurs in veins in crystalline rocks. Sahlberg in Sweden, Allemont in Dauphine, Przibram, in Bohemia, Andreasberg in the Hartz. Used as an alloy to harden the softer metals, particularly type metal; it is also used for some pharmaceutical preparations.

Antimonsilber.—*Antimonial Silver.*—Ag^4 Sb. **prismatic.** H 3·5 G 9·4 — 9·8. Case 3. Soluble partially in nitric acid. B. easily fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* silver white. *Str.* the same.

Occurs in veins in granite, porphyry, and crystalline slate rocks. Andreasberg in the Hartz, Guadal canal in Spain, Allemont in France, Mexico. A rare mineral, highly valuable for extracting silver, when found in sufficient quantity.

Breithauptite.—*Nickel Antimonial.*—Ni^2 Sb. **rhombohedral.** H 5·0 G 7·54. Soluble in nitro-muriatic acid. B. volatilizes. *Frac.* uneven-conchoidal. Opaque. *Lus.* metallic. *Col.* light copper-red. *Str.* reddish-brown. Brittle.

Occurs with ores of cobalt at Andreasberg in the Hartz.

Arsenic.—*Native Arsenic.*—As. **rhombohedral.** H 3·5 G 5·7 — 5·8. Case 4. With nitric acid changes to arsenious acid. B. easily fusible, on charcoal volatilizes. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* tin-white. *Str.* the same. Brittle.

Occurs in veins, seldom in beds, in crystalline slate rocks. The Hartz, Saxony, Baden, Bohemia, Transylvania, the Banat, Dauphine, Alsace, Norway. A virulent poison, it is used in metallurgical processes and in the manufacture of glass and colours.

Kupfernickel.—*Copper Nickel, Arseniate of Nickel.*—Ni^2 As. **rhombohedral.** H 5·5 G 7·2 — 7·8. Case 4. Soluble in nitro-chloric acid. B. fusible. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* copper-red. *Str.* brownish-black. Brittle.

Occurs in veins, seldom in beds, in granite, clay, slate, and transition rocks. Saxony, Bohemia, Thuringia, Hessia, the Hartz, Baden, Dauphine, Styria, the Banat, Spain, Connecticut, Cornwall, Linlithgowshire. Distinguished from native copper by its brittle nature, and the green deposit it forms in nitric acid.

Rammelsbergite.—*White Arsenical Nickel.*—Ni. As. **cubic.** H 5·5 G 6·43 — 6·73. Case 4. Soluble in nitric acid. B. easily fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* tin-white. Brittle.

Found at Schneeberg in Saxony, Richelsdorf in Hessia, Kamsdorf near Saalfield.

Chloanthite.—*White Nickel.*—Ni. As. **prismatic.** H 5·5 G 7·09 — 7·18. Opaque. *Lus.* metallic. *Col.* tin-white.

Found at Riechelsdorf and Schneeberg.

Smaltine.—*Tin-white Cobalt, Arsenical Cobalt.*—Co. As. **cubic.** H 5·5 G 6·3 — 6·6. Case 4. Soluble in nitric acid. B. easily fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* tin-white. *Str.* grayish-black.

Found in veins in slate rocks. Saxony, Bohemia, Hessia, Styria, Hungary, Piedmont, Cornwall. Distinguished from native bismuth and copper nickel by its perfect cleavage, inferior hardness, and reddish tinge. Roasted to drive off the arsenic, and finely powdered, it affords a blue colour for painting porcelain, &c.; with silex and potash it produces smalt.

Safflorite.—*Cobalt Arsenical, Chathamite, Iron Cobalt.*—Co. As. and Fe. As. **cubic.** H 5·5 G 6·92 — 7·3. Soluble in nitric acid. *Frac.* uneven. *Col.* light steel-gray.

Found in veins traversing primitive rocks. Schneeberg.

Skutterudite.—*Modumite, Hard white Cobalt.*—Co^2 As^3 **cubic.** H 6·0 G 6·74 — 6·84. Case 4. Soluble in nitric acid. B. easily fusible. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* tin-white.

Found in mica state, at Skutterud in Norway.

Lolingite.—*Arsenical Pyrites, Leucopyrite.*—$Fe.^4$ $As.^3$ **prismatic.** H 5·5 G 7·0 — 7·3. Soluble in nitric acid, partially. B. fusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* silver white. *Str.* grayish-black.

Found in veins in clay slate, in beds of chalybite, and in serpentine. Andreasberg, Carinthia, Styria, Silesia, Norway. The accidental admixture of silver renders some of the varieties of this species useful as an ore of that metal. It is employed in the manufacture of white arsenic and of realgar. Sometimes it contains a small portion of gold.

Placodine.—$Ni.^4$ As. **oblique.** H 5·0 — 5·5 G 7·99 — 8·06. Soluble in nitric acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* between bronze-yellow and copper-red. *Str.* black. Brittle.

Found at Müsen in Siegen.

Domeykite.—*Arseniuret of Copper, Condurrite.*—$Cu.^6$ As. H 3·5 G 4·20 — 4·29. Case 4. Not soluble in hydro-chloric acid. B. easily fusible. Opaque. *Lus.* metallic. *Col.* tin-white.

Found in veins in porphyritic mountains. Peru, Chili, Cornwall.

Diamond.—C. **cubic.** H = 10·0 G – 3·5 – 3·6. Case 4. Insoluble in acids *Frac.* conchoidal. Transparent-translucent. *Lus.* adamantine. *Col.* colourless, white, gray, brown, green, yellow, red, blue, rarely black. *Str.* gray.

Found in quartz, conglomerate, in strata of clay and sand containing an iron oxide, in alluviums, and in a micaceous sandstone. The Deccan, Malacca, Borneo, Celebes, Java, Brazils, Mexico, the Ural, North Carolina, Georgia. The most valued of all the gems. Employed for cutting glass, and its powder for cutting and polishing hard gems and stones.

Graphite.—*Plumbago, Carburet of Iron.*—C. **rhombohedral.** H 1·0 – 2·0 G 1·8 — 2·1. Case 4. Insoluble in acids. B. infusible. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* iron-black, dark steel gray. *Str.* black, shining.

Found in beds in gneiss, trap, and in the coal formation. Norway, Bavaria, the Pyrenees, North America, Austria, Styria, Bohemia, Moravia, Cumberland, Aberdeenshire, Kilkenny, Ayrshire, Spain, Ceylon, the Brazils, Massachusetts. Used for the manufacture of pencils and crucibles; also to diminish friction in machines.

Anthracite.—*Glance Coal.* H 2·0 – 2·5 G 1·3 – 1·75. Case 4. *Frac.* conchoidal. *Lus.* vitreous or waxy. *Col.* black. *Str.* black. Brittle.

Found in several parts of the Alps, the Pyrenees, France, Pennsylvania, Massachusetts, Bohemia, Silesia, Saxony, Staffordshire, Brecknockshire, Carmarthenshire, Pembrokeshire, Kilmarnock, and Kilkenny. Used as fuel for furnaces, and in the manufacture of metals.

Selenium.—Se. Case 4. H 2·0 G 4·3. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* pale dull red.

Found incrusting sulphur in Sicily, Mexico.

Berzeline.—*Seleniuret of Copper.*—$Cu.^2$ Se. Case 4. Crystalline. *Lus.* metallic. *Col.* silver-white. *Str.* shining. Soft and malleable.

Found coating calcite at Skrickerum, Sweden, rarely in the Hartz.

Eukairite.—*Seleniuret of Silver and Copper.* $Cu.^2$ Se. + Ag. Se. Case 4. Soluble in hot nitric acid. B. fusible. Crystalline. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* shining. Soft.

Found in serpentine at Skrickerum, Sweden.

Naumannite.—*Seleniuret of Silver.*—Ag. Se. **cubic.** H 2·4 G 8·0. Soluble in concentrated nitric acid. B. fusible. Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* same. Malleable.

Found in narrow veins in diabase at Tilkerode in the Hartz.

Clausthalite.—*Seleniuret of Lead.*—Pb. Se. **cubic.** Case 4. H 2·5 — 3·0 G 8·2 — 8·8. Soluble in nitric acid partially. B. volatilizes. Opaque. *Lus.* metallic. *Col.* Lead-gray. *Str.* gray.

Found in transition rocks in the Hartz and Saxony.

Lerbachite.—*Seleniuret of Lead and Mercury.*—Pb. Se. and Hg. Se. Case 4. **Cubic.** Soft. G 7·3. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* black.

Found in transition rocks in the Hartz.

Zorgite.—*Seleniuret of Lead and Copper.*—Pb. Se. with Cu. Se. Case 4. H 2·5 G 7·0 — 7·5. B. volatilizes. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* light lead gray, grass-yellow. *Str.* darker than colour.

Found in transition rocks and in a vein in clay slate. The Hartz and Thuringia.

Riolite.—Ag. $Se.^2$ **rhombohedral.** Colour lead-gray. Very malleable.

Found in Tasco in Mexico.

Onofrite.—*Seleniuret of Mercury.*—Hg. Se. with Hg. S. Case 4. H 2·5. *Lus.* metallic. *Col.* blackish, lead-gray. *Str.* shining.

Found massive in veins at San Onofre, Mexico.

Sulphur.—S. **prismatic.** H 1·5 — 2·5 G 2·0 — 2·1. Case 5. *Frac.* conchoidal, uneven. Transparent. Translucent on the edges. *Lus.* resinous, inclining to adamantine. *Col.* sulphur-yellow, passing into red-brown, gray. *Str.* sulphur, yellow-white.

Found in mica slate, lime-stone, metallic veins, beds of gypsum, sandstone, in alluvium, as a volcanic sublimate, and a deposit from hot springs, Anito, Hungary, the Black Forest, Sicily, Tuscany, Spain, Cracow, Hanover, Greenland, Thuringia, Naples, Ætna, Iceland, Java, Teneriffe, Bourbon. Used in the manufacture of gunpowder, sulphuric acid, cinnabar, and various pharmaceutical preparations.

Alabandine.—*Sulphuret of Manganese, Hexahedral Glance Blende.*—Mn. S. **cubic.** H 4·0 — G 3·95 — 4·01. Case 5. *Frac.* uneven, imperfect, conchoidal. Opaque. *Lus.* metallic, imperfect. *Col.* iron-black. *Str.* dark-green. B. fusible. Soluble in hydrochloric acid.

A rare mineral, found in veins. Nagyag, Transylvania, and in Mexico.

Hauerite.—Mn. S^2. **cubic.** H 4·0 — G 3·46. Case 5. *Lus.* adamantine. *Col.* dark reddish-brown. *Str.* brownish-red

Found in clay with gypsum, and sometimes with sulphur. Kalinka, Hungary.

Blende.—*Sulphuret of Zinc, Dodecahedral Garnet Blende, Black Jack of Miners.*—Zn. S. **cubic.** H 3·5 — 4·0 G 3·9 — 4·2. Case 5. *Frac.* conchoidal. *Lus.* adamantine. *Col.* green, yellow, red, brown, and black. Transparent. B. fusible with difficulty. Soluble in powder in concentrated nitric acid, with exception of the sulphurs.

Widely diffused in veins and beds, in crystalline slate and transition rocks. Hungary, Transylvania, Bohemia, Saxony, the Hartz, Sweden, Derbyshire, Flintshire, Cornwall, Perthshire, Leadhills, and Lanarkshire. Distinguished from the varieties of galena, garnet, and tin, which it resembles by the facility with which it yields to the knife. Of little value as an ore of zinc, from the difficulty of extracting that metal from it.

Pyrite.—*Iron Pyrites, Sulphuret of Iron, Hexahedral Iron Pyrites.* Fe. S^2. **cubic.** H 6·0 — 6·5 G 4·9 — 5·1. Case 6. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* brass-yellow, gold-yellow, brown. Brittle. B. fusible. Partly soluble in nitric acid. Some varieties contain a small quantity of gold.

A very common mineral, universally diffused in beds and veins of the most different formations. Elba, Piedmont, Saxony, Bohemia, Hungary, Norway, Sweden, Dauphine, Derbyshire, Cornwall, &c. Used in the manufacture of sulphur, sulphate of iron, and sulphuric acid. Distinguished from copper pyrites by being too hard to be cut by a knife; from the ores of silver by its pale bronze colour, and hardness and difficulty of fusion. Gold is sectile, malleable, and does not give off a sulphur odour before the blow-pipe.

Marcasite.—*White Iron Pyrites. Prismatic Iron Pyrites.*—Fe. S^2 **prismatic.** H 6·0 — 6·5 G 4·65 — 4.9. Case 6. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* pale bronze-yellow, sometimes inclining to green or gray. *Str.* dark greenish-gray. Brittle.

Not so common as pyrite, and not found in the older rocks. Saxony, Bohemia, Hessia, the Hartz, Condé, Cornwall, Derbyshire. Used for the same purposes as pyrite.

Pyrrhotine.—*Rhombohedral or Magnetic Iron Pyrites.* 5 Fe. S + $Fe.^2 S^3$ = $Fe.^7 S^8$ **rhombohedral.** H 3·5 – 4·5 G 4·6 – 4·7. Case 6. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* brass-yellow. *Str.* grayish-black. Feebly magnetic. Brittle.

Occurs principally in beds in the older rocks, and sometimes in meteorites. The Hartz, Bavaria, Saxony, Silesia, Cornwall, Argyleshire, and Galloway.

Linneite.—*Sulphuret of Cobalt. Isometrical Cobalt-kies.*—Co. S + $Co.^2 S^3$ **cubic.** H 5·5 G 4·8 — 5·0. *Frac.* conchoidal-uneven. Opaque. *Lus.* metallic. *Col.* silver-white, inclining to steel-gray. *Str.* blackish-gray. Brittle. B. fusible. Partly soluble in warm nitric acid.

Found in Sweden in beds of gneiss.

Syepoorite.—*Sulphuret of Cobalt.*—Co. S. *Col.* steel-gray, inclining to yellow.

Found in Syepoor, in Hindostan.

Millerite.—*Sulphuret of Nickel. Nickel Pyrites. Native Nickel.*—Ni. S. **rhombohedral.** H 3·5 G 5·26 – 5·30. Case 6. Opaque. *Lus.* metallic. *Col.* brass-yellow. *Str.* bright. B. easily fusible. Soluble in nitro-muriatic acid. Green.

Occurs in cavities, and dispersed among the crystals of other minerals. Bohemia, Saxony, Andreasberg, and Cornwall.

Eisennickelkies,—2 Fe. S + Ni. S. **cubic.** H 3·5 – 4·0 G 4·6. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* light pinchbeck-brown. *Str.* rather darker. Brittle.

Found in crystalline masses with towanite in amphibole, Norway.

Gersdorfitte.—*Disomose. Arsenical Nickel.*—Ni. S^2 + Ni. As^2 or 2 Ni. S + Ni. As^2 **cubic.** H 5·0 — 5·5 G 6·1 – 6·13. Case 6. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* Light lead-gray. *Str.* grayish-black. Brittle. B. fusible. Partially soluble in nitric acid.

The Hartz, Sweden, Hungary, Spain, and the Brazils.

Ullmanite.—*Nickeliferous Gray Antimony. Hartmannite.*—Ni. Sb + Ni. S^2 **cubic.** H 5·0 – 5·5 G 6·2 — 6·55. Case 10. Opaque. *Lus.* metallic. *Col.* gray.

Str. grayish-black. Brittle. B. fusible. Partially soluble in nitro-muriatic acid, forming a green solution.

Found in iron-stone veins. Nassau, Prussia, and the Hartz.

Grunauite.—*Saynite. Nickel Bismuth Glance. Bismuthiferous Sulphuret of Nickel.* **cubic.** H 4·5 G = 5·13. Opaque. *Lus.* metallic. *Col.* light steel-grey. *Str.* dark gray. Brittle. B. fusible. Green solution in nitric acid.

Found in veins. Bohemia and Cornwall.

Greenockite.—*Sulphuret of Cadmium.* Cd. S. **rhombohedral.** H 3·8 G 4·8 – 4·9. Case 6. Translucent. *Lus.* adamantine. *Col.* yellow. *Str.* orange. Soluble in warm hydrochloric acid.

Occurs in crystals in porphyritic amygdaloidal trap, at Bishopton, in Renfrewshire.

Redruthite.—*Vitreous Copper. Prismatic Copper Glance.*—$Cu.^2$ S. **prismatic.** H 2·5 — 3·0 G 5·5 . . . 5·8. Case 7. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* the same, shining. Very sectile. B. easily fusible. Blue solution in warm nitric acid.

Found in beds and veins in bituminous copper slate, iron stone and clay slate. Silesia, the Hartz, Sweden, Norway, North America, Peru, Mexico, Cornwall, Yorkshire, Ayrshire, the Orkneys, and Shetland. $Cu.^2$ S. formed by the fusion of copper glance, or of copper and sulphur in the same proportions, can be obtained in octahedral crystals; this substance is therefore dimorphous. It is a rich and highly valuable ore of copper.

Covelline.—*Kupferindig. Indigo Copper. Blue Copper.*—Cu. S. **rhombohedral.** H 1·5 — 2·0 G 3·8 — 3·82. Case 7. Opaque. *Lus.* resinous. *Col.* indigo-blue. *Str.* black, shining. Sectile. B. fusible. Soluble in nitric acid.

Found in Thuringia, Salzburg, Poland, Vesuvius.

Tennantite.—*Dodecahedral dystome Glance.*—4 (Fe, 2Cu.) S + As. S^3 **cubic.** H 4·0 G 4·3 – 4·5. Case 7. Opaque. *Lus.* metallic. *Col.* blackish lead-gray—iron-black. *Str.* dark reddish-gray. Brittle. B. fusible.

In veins in granite and clay slate. Redruth, and St. Day, in Cornwall.

Bornite.—*Purple Copper. Variegated Copper. Octahedral and Hepatic Copper Pyrites. Buntkupfererz. Erubescite.*—3 $Cu.^2$ S + $Fe.^2$ S^3 **cubic.** H 3·0 G 4·9 – 5·1. Case 7. *Frac.* conchoidal-uneven. Opaque. *Lus.* metallic. *Col.* between copper-red and pinchbeck-brown . *Str.* grayish-black. Rather sectile. B. fusible. Partially soluble in concentrated hydrochloric acid.

Found in beds and veins of the older rocks. The Banat, Norway, Thuringia, Silesia, Siberia, Greenland, Sweden, North America, Saxony, the Hartz, Cornwall. A valuable mineral for extracting copper.

Cubane.—$Cu.^2$ S $Fe.^2$ S^3 + 2 Fe S or Cu. S + $Fe.^2$ S^3 **cubic.** H 4·0 G 4·026 – 4·042. Opaque. *Lus.* metallic. *Col.* brass-yellow. *Str.* black. B. fusible.

Found at Bacaranao in Cuba.

Towanite.—*Pyramidal Copper Pyrites. Yellow Copper Ore. Chalkopyrite.*—$Cu.^2$ S + $Fe.^2$ S^3. **pyramidal.** H 3·5 — 4·0 G 4·1 — 4·3. Case 7. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* brass-yellow. *Str.* greenish-black. Slightly brittle. B. fusible. Soluble partially in nitro-muriatic acid. It sometimes contain traces of silver or gold.

Occurs in beds and veins with several other minerals. Saxony, Bohemia, Norway

Sweden, the Hartz, Cornwall, Anglesea, Derbyshire, Cumberland, Perthshire, Shetland, Wicklow, Hungary, Siberia, North and South America, Africa, Japan. An important ore of copper. Also used in the manufacture of blue vitriol, or sulphate of copper.

Patrinite. — *Plumbo cupriferous sulphuret of Bismuth. Nadelerz Needle Ore Arikinite. Aciculite*—$(3Cu.^2 S + Bi. S^3) + 2 (Pb.^3 S + Bi. S^3)$ **prismatic.** H 2·0 — 2·5 G 6·75. Opaque. *Lus.* metallic. *Col.* Blackish lead-gray. *Str.* blackish-gray. Slightly brittle. B. easily fusible. Partially soluble in nitric acid.

Imbedded in quartz, associated with gold. Beresow in Siberia.

Stromeyerite.—*Sulphuret of Silver and Copper. Argentiferous Copper Glance.*—$Cu.^2 S + Ag. S$ **prismatic.** H 2·5 — 3·0 G 6·255. Case 10. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* the same, shining. Perfectly sectile. B. fusible. Partially soluble in nitric acid.

A rare mineral. Schlangenberg in Siberia, Chile, Silesia.

Galena.—*Sulphuret of Lead, Hexahedral Lead Glance, Blue Lead.*—Pb S, **cubic.** H 2·5 G 7·4 . . . 7·6. Case 8. B. fusible. Soluble, partially in nitric acid. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* the same. Rather sectile.

Occurs very abundantly in rocks of the most different formations. Saxony, Bohemia, the Hartz, Hungary, France, Norway, Sweden, Spain, Silesia, North America, Greenland, Cumberland, Durham, Northumberland, Flintshire, Wales, several places in Scotland. This is the ore which yields most of the lead which is produced; it sometimes contains a small quantity of silver, which is extracted from it. Galena reduced to powder, or the litharge produced from it, is used for glazing coarse pottery.

Steinmannite.—*Octahedral Lead Glance.*—$Pb S, Sb S^3$, **cubic.** H 2·5. G 6·83. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* gray, shining. Sectile. B. fusible.

Found at Pezibram, in Bohemia, with silver, blende, pyrite, and quartz.

Bismuthine.—*Sulphuret of Bismuth, Prismatic Bismuth Glance.*—$Bi S^3$ **prismatic.** H 2·0 G 6·4 — 6·5. Case 9. *Frac.* imperfect, conchoidal. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* the same. B. easily fusible. Soluble easily in nitric acid.

Rather a rare mineral. Sweden, Saxony, Bohemia, Norway, Siberia, Cornwall, and Cumberland.

Stannine.—*Sulphuret of Tin, Tin Pyrites.*—$(2Cu^2 S + Sn S^2) + (2Fe S + Sn S^2)$ **cubic.** H 4·0 G = 4·3 — 4·51. Case 9. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* steel-gray, inclining to bronze-yellow. *Str.* black. Brittle. B. fusible. Blue solution in nitric acid.

Found in veins in Bohemia and Cornwall. Sometimes called bell-metal ore, from its yellowish tinge; distinguished from copper pyrites, and fahlerz by its colour and black streak.

Cinnabar.—*Sulphuret of Mercury, Peritomous Ruby Blende.*—Hg S **rhombohedral.** H 2·5 — G 8·0 — 8·2. Case 9. Semitransparent, translucent on the edges. *Lus.* adamantine. *Col.* cochineal-red, passing into lead-gray and scarlet-red. *Str.* scarlet. Sectile. Soluble in nitro-muriatic acid.

In beds and veins. Spain, Syria, Bohemia, Saxony, the Hartz, the Ural, Mexico, Peru, China, Japan. It is the most abundant and important ore of mercury. *Vermilion* is pure cinnabar, and is used as a pigment and in colouring red sealing-wax.

Argentite.—*Sulphuret of Silver, Henkelite, Hexahedral Silver Glance.*—Ag S **cubic.** H 2·0 — 2·5 G 7·196. Case 10. *Frac.* uneven, hackly. Opaque. *Lus.* metallic. *Col.* blackish, lead-gray. *Str.* shining. Malleable. B. fusible. Soluble partially in concentrated nitric acid.

Found in veins. Saxony, Norway, Bohemia, Hungary, the Hartz, Spain, Sardinia, Siberia, Mexico, Peru, Cornwall. A valuable silver ore.

Sternbergite. — *Flexible Silver, Prismatic Eutom Glance.* — Ag S + $2Fe^2 S^3$ **prismatic.** H 1·0 — 1·5 G 4·215. Case 10. *Lus.* metallic. *Col.* pinchbeck-brown. *Str.* black. Sectile. B. fusible. Decomposible by nitro-muriatic acid, leaving sulphur and chloride of silver.

Found in veins with pyrargyrite and argentite. Bohemia and Saxony.

Antimonite.—*Sulphuret of Antimony, Gray Antimony, Prismatic Antimony Glance.*—Sb S^3 **prismatic.** H 2·0 G 4·6 — 4·7. Case 10. *Frac.* conchoidal, imperfect. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* lead-gray. Sectile. B. fusible. Soluble in warm hydrochloric acid.

Found in veins in granite and slate rocks. Hungary, Transylvania, Saxony, the Hartz, France, Tuscany, Cornwall, Spain, North and South America. Almost the only ore of antimony found in sufficient quantities for commercial purposes.

Plumosite.—*Capillary Sulphuret of Antimony, Federerz.* — 2 Pb S + Sb S^3 H 3·0 G 5·7 — 5·9. Case 10. Opaque. *Lus.* metallic, feeble. *Col.* blackish lead-gray. Sectile.

Found in flexible, fine, capillary crystals in veins with antimonite, galena, &c. The Hartz.

Bournonite. —*Plumbo-cupriferous Sulphuret of Antimony, Diprismatic Copper Glance.*—(3 Cu^2 S + Sb S^3) + 2(3 Pb S + Sb S^3) **prismatic.** H 2·5 — 3·0 G 5·70 — 5·87. Case 11. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* steel-gray *Str.* the same. Brittle. B. fusible. Partially soluble in nitric acid.

Found in veins in slate rocks. The Hartz, Saxony, Transylvania, Hungary, Savoy, France, Piedmont, Cornwall, Devonshire, Siberia, Mexico. Used as a copper ore when found in sufficient quantity.

Wolchite.—*Antimonial Copper Glance.*—**prismatic.** H 3·0 G 5·7 — 5·8. *Frac.* imperfect, conchoidal. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* the same. Brittle. B. fusible.

Found in a bed of chalybite at St. Gretrand in Carinthia.

Wolfsbergite.—*Sulphuret of Copper and Antimony.*—Cu^2 S + Sb S^3 **prismatic.** H 3·5 G 4·748. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* lead-gray, iron-black. *Str.* black, dull. B. fusible.

Found with quartz and other minerals at Wolfsberg in the Hartz.

Boulangerite.—*Sulphuret of Antimony and Lead, Embrithite.*—3 Pb S + Sb S^3 H 3·0 G 5·96 — 6·0. Case 11. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* darker. Slightly brittle. B. fusible. Soluble in warm hydrochloric acid.

Found in granular or fibrous masses. France, Sayn, Lapland, Siberia.

Schulzite.—*Geokronite, Kilbrickenite.*—5 Pb S + Sb S^3 **prismatic.** H 2·5 — 3·0 — G 5·8 — 6·54. *Frac.* conchoidal, even. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* the same. Brittle. B. easily fusible.

Found in galena. Spain, Tuscany, Sweden, Ireland.

Zinckenite.—*Rhombohedral Dystom Glance.*—Pb S + Sb S^3 **prismatic.** H 3·0 — 3·5 G 5·30 — 5·35. Case 11. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* dark steel-gray. *Str.* the same. Slightly brittle. B. fusible. Decomposed by warm hydrochloric acid, forming chloride of lead.

Found in a vein with antimonite and quartz at Wolfsberg, in the Hartz, and near St. Trudport in the Black Forest.

Jamesonite.—*Axotomous Antimony Glance.*—3 Pb S + 2 Sb S^3 **prismatic.** H 2·0 2·5 G 5·564 – 5·616. Case 11. Opaque. *Lus.* metallic. *Col.* steel-gray. *Str.* the same. Ductile. B. easily fusible. Decomposed by warm hydrochloric acid, forming chloride of lead.

Found sometimes with bournonite. Cornwall, Estramadura, Hungary, France, Siberia, Brazils.

Berthierite.—*Haidingerite, Sulphuret of Antimony and Iron.*—Fe. S + Sb S^3 H 2·0 . . . . 3·0 G 4·0 — 4·3. Case 11. *Frac.* uneven. *Lus.* metallic. *Col.* iron-black. B. fusible. Soluble in hydrochloric acid.

Found in crystalline masses in gneiss. Auvergne, La Creuse, Saxony, Hungary. Yields antimony of such inferior quality that the manufacturers cannot use it.

Stephanite.—*Brittle Sulphuret of Silver, Prismatic Melane Glance, Black Sulphuret of Antimony and Silver.*—6 Ag S + Sb S^3 **prismatic.** H 2·5 G 6·2 — 6·3. Case 11. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* the same. Sectile. B. fusible.

Found in veins in crystalline slate rocks, transition rocks, trachyte. Saxony, Bohemia, Hungary, the Hartz, Mexico. This is a valuable ore of silver.

Proustite.—*Red Silver, Ruby-blende.*—3 Ag S + As S^3 **rhombohedral.** H 2·0 — 2·5 G 5·5 — 5·6. Case 11. *Frac.* conchoidal, uneven. Semi-transparent. *Lus.* adamantine. *Col.* cochineal-red, carmine-red. *Str.* Aurora-red. Slightly sectile. B. easily fusible. Soluble partially in nitric acid.

Found with other minerals in veins. Saxony, Bohemia, Baden, Alsace, Dauphiné, Spain, Mexico, Peru.

Pyrargyrite.—*Red Silver, Sulphuret of Silver and Antimony, Rhombohedral Ruby-blende.* 3 Ag S + Sb S^3 **rhombohedral.** H 2·0 – 2·5 G 5·75 – 5·85. Case 11. *Frac.* conchoidal. Translucent on the edges. Opaque. *Lus.* adamantine. *Col.* adamantine-red, blackish lead-gray. *Str.* cochineal-red, cherry-red. Slightly sectile. B. easily fusible. Soluble partially in nitric acid.

Found in veins in crystalline slate and transition rocks, granite and trachyte. The Hartz, Saxony, Bohemia, Baden, Hungary, Mexico, Cornwall. Distinguished from red orpiment by the yellow streak of the latter and its specific gravity; from cinnabar by forming a metallic globule before the blowpipe. A valuable ore of silver.

Miargyrite.—*Hemiprismatic Ruby-blende.*—Ag S + Sb S^3 **oblique.** H 2·5 G 5·3 – 5·4. Case 11. *Frac.* imperfect, conchoidal. Opaque. *Lus.* adamantine. *Col.* blackish lead-gray. In thin splinters,—blood-red by transmitted light. *Str.* Cherry-red. Very sectile.

A very rare mineral, from Baünsdorf, in Saxony.

Kobellite.—*Sulphuret of Antimony, Lead, and Bismuth.*—(3 Fe S + 2 Sb^2 S^3) + 4 (3 Pb S + Bi^2 S^3). Soft. G 6·29 — 6·32. Case 11. Opaque. *Lus.* metallic. *Col.* dark lead-gray. *Str.* black.

Found in the cobalt mine of Hvena, Sweden.

Kermes.—*Red Antimony, Prismatic Purple Blende Sulphuret of Oxide of Antimony.* —Sb O^2 + 2 Sb S^3 **oblique.** H 1·5 G 4·5 — 4·6. Case 38. Faintly translucent. *Lus.* adamantine. *Col.* cherry-red. *Str.* the same. Sectile. B. fusible. Soluble in hydrochloric acid.

Found in veins in crystalline, slate, and transition rocks. Saxony, Bohemia, Hungary, Dauphiné.

Plagionite.—*Hemiprismatic Dystom Glance.*—4 Pb S + 3 Sb S^3 **oblique.** H 2·5 G 5·4. Case 12. *Frac.* imperfect, conchoidal. Opaque. *Lus.* metallic. *Col.* blackish lead-gray. *Str.* the same. Brittle. B. fusible.

Found in a vein of quartz. Wolfsberg, in the Hartz.

Feuerblende.—H 2·0 G 4·2 **oblique.** Translucent. *Lus.* pearly. Sectile and rather flexible.

Found in the Kurprinz, near Freiberg, and at Andreasberg.

Fahlerz.—*Gray Copper, Tetrahedral Copper Glance.* (4 Pb S, 4 Fe S, 4 Zn S, 4 Cu^2 S) + Sb S^3 **cubic.** H 3·0 — 4·0 G 4·5 — 5·2. Case 12. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* steel-gray, iron-black. *Str.* black, dark red. Rather brittle. B. fusible. Decomposed by nitric acid.

Found in beds and veins. The Hartz, Nassau, Tyrol, Transylvania, Hungary, Bohemia, Siberia, Mexico, Chili, Peru, Cornwall, Devonshire, East Lothian. Accompanies copper pyrites, is worked as a copper ore, also occasionally for the silver it contains.

Freieslebenite.—*Sulphuret of Silver and Antimony, Peritomous Antimony Glance.*—(Ag S + Sb S^3) + 2 (3 Ag S + Sb S^3), the Ag is sometimes replaced by Pb. **Oblique.** H 2·5 G 6·19 — 6·38. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* steel-gray. *Str.* the same. Brittle. B. fusible.

A very rare mineral, found in veins in gneiss, Freiburg in Saxony.

Orpiment.—*Yellow Sulphuret of Arsenic, Prismatoidal Sulphur.* As. S^3 **prismatic.** H 1·5 — G 3·48. Case 12. Semi-transparent, translucent on the edges. *Lus.* resinous. *Col.* lemon yellow. Sectile. Soluble in nitro-muriatic acid.

Found in beds and in veins. The Hartz, St. Gotthardt, the Tyrol, Solfatara, Vesuvius, Guadaloupe, Japan. Employed as a pigment.

Realgar.—*Red Sulphuret of Arsenic, Hemiprismatic Sulphur.*—As. S^2 **oblique.** H 1·5 G 3·556. Case 12. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* resinous. *Col.* aurora red. *Str.* orange yellow. Sectile. B. fusible. Partially soluble in hot nitro-muriatic acid.

Found in veins. Transylvania, Hungary, Bohemia, Saxony, the Hartz, Baden, Hungary, St. Gotthardt, the Tyrol, Peru, United States, Vesuvius, Ætna, Japan. Used as a pigment.

Mispickel.—*Arsenical Iron, Prismatic Arsenical Pyrites.*—Fe S^2 + Fe As. **prismatic.** H 5·5 G 6·0 — 6·3. Case 12. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* silver-white. *Str.* grayish-black. Brittle. B. fusible. Soluble in nitric acid.

Found in veins and beds. Saxony, Bohemia, Silesia, Hungary, Transylvania, Sweden, Cornwall, Norway, United States. Worked as an ore of arsenic, the white oxide of commerce being principally obtained from it.

Dufrenoysite.—2 Pb S + As S^3 **cubic.** G 5·549. *Frac.* uneven. Opaque. *Lus.* metallic. *Col.* steel-gray. *Str.* reddish-brown. Brittle. B. fusible. Decomposed by hot nitric acid.

Found in narrow veins in the dolomite of St. Gotthardt.

Xanthocone.—(3 Ag S + As S^3) + 2 (3 Ag S + As S^4). **rhombohedral.** H 2·0 – 3·0 G = 5·158 – 5·191. *Frac.* conchoidal, uneven. Transparent, translucent. *Lus.* adamantine. *Col.* orange yellow-brown. *Str.* the same, darker. Brittle. B. fusible.

Found in the Himmelsfürst mine near Freiberg in Saxony.

Cobaltine.—*Bright White Cobalt, Hexagonal Cobalt Pyrites, Cobalt Glance.*—Co S^2 + Co As. **cubic.** H 5·5 G 6·1 – 6·3. Case 12. *Frac.* imperfect, conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* silver-white. *Str.* grayish-black. Brittle. B. fusible. Soluble in warm nitric acid.

Found in beds in crystalline rocks. Norway, Sweden, Silesia, the Banat.

Glaucodote.—R S^2 + R As where R is Co and Fe. **prismatic.** H 5·0 G = 5·975 – 6·003. Opaque. *Lus.* metallic. *Col.* dark tin-white. *Str.* black. B. fusible.

Found in veins in chlorite slate. Huasko in Chili.

Molybdenite.—*Sulphuret of Molybdena, Dirhombohedral, Eutom Glance.*—Mo S^2. **rhombohedral.** H 1·0 – 1·5 G 4·5 – 4·6. Case 12. Opaque. *Lus.* metallic. *Col.* lead-gray. *Str.* the same. Very sectile. Green solution with hot nitric acid.

Saxony, Bohemia, Sweden, Norway, France, United States, Peru, the Brazils, Cornwall, Cumberland, Westmoreland, Inverness-shire.

Voltzine.—4*Zn*S + ZNS. H 4·5 G 3·66. *Frac.* conchoidal, translucent on the edges. Opaque. *Lus.* pearly. *Col.* brick-red.

Found in a vein of quartz. Rosières, Puy de Dome in France, and in some zinc furnaces.

Manganite.—*Gray Oxide of Manganese, Prismatoidal Manganese Ore.*—Mn^2O^3 + HO. **prismatic.** H 3·5 — 4·0 G 4·22 — 4.34. Case 13. Opaque. *Lus.* metallic, imperfect. *Col.* dark steel-gray, brownish, black-velvet-black. *Str.* reddish-brown. Brittle. B. infusible. Soluble in hydrochloric acid.

Found in veins in porphyry, gneiss, and cavities of amygdaloidal trap. The Hartz, Thuringia, Aberdeenshire, Norway, Sweden, Nova Scotia. The purest and most beautifully crystallized ore of manganese.

Pyrolusite.—*Prismatic oxide of Manganese, Anhydrous Peroxide of Manganese.*—MnO^2. **prismatic.** H 2·0 – 2·5 G 4·7 — 5·0. Case 13. *Frac.* uneven. Opaque. *Col.* dark steel-gray, light iron-black. Brittle. B. infusible. Soluble in hydrochloric acid.

Found at Thuringia, Moravia, the Hartz, Saxony, Bohemia, Austria, Silesia, the Brazils. It is an ore of manganese most extensively worked in many countries. It derives its name from πυρ *fire*, and λουω *I wash*, on account of its property of clearing glass from its brown and green tints, a property which makes it of great value to the manufacturer. *Varvasite* is supposed to be a mechanical mixture of *pyrolusite* and *manganite*.

Polianite.—MnO^2. **prismatic.** H 6·5 — 7·0 G 4·838 — 4·880. Case 13. Opaque. *Lus.* metallic, feeble. *Col.* light steel-gray. *Str.* gray. B. infusible. Soluble in hydrochloric acid.

Found in Bohemia, Saxony, and Siegen.

Psilomelane.—*Uncleavable Manganese Ore, compact and fibrous Manganese Ore, or Black Hematite.*—**Amorphous.** H 5·0 — 6·0 G 3·7 — 4·4. Case 13. *Frac.*

even, flat, conchoidal. Opaque. *Lus.* metallic, imperfect. *Col.* bluish-black, grayish-black, dark steel-gray. *Str.* brownish-black, shining. Brittle.

The Hartz, Saxony, Styria, Siegen, Black Forest, Silesia, Bohemia, Hungary, Norway, Devonshire, Cornwall, North America. One of the most widely diffused ores of manganese; it derives its name ψιλός smooth, and μελας black, from its black colour and smooth botryoidal shapes.

Braunite.—*Brachytypous Manganese Ore.*—Mn^2O^3, **pyramidal.** H 6·0 — 6·5 G 4·8 — 4·9. Case 13. *Frac.* uneven. Opaque. *Lus.* metallic, imperfect. *Col.* dark brownish-black. *Str.* brownish-black. Brittle. B. infusible. Soluble in hydrochloric acid.

Found in veins in quartzose porphyry. Thuringia, Mannsfeld, Westphalia, Piedmont. Distinguished from other ores of manganese by its hardness.

Hausmannite.—*Pyramidal Manganese Ore, Black Manganese.*—$MnO + Mn^2O^3$, **pyramidal.** H 5·0 — 5·5 G 4·7 — 4·8. Case 13. *Frac.* uneven. Opaque. *Lus.* imperfect metallic. *Col.* brownish-black. *Str.* dark reddish-brown. B. infusible. Soluble in warm hydrochloric acid.

Found in veins in porphyry. Oehrenstock in Thuringia, Shelefield in the Hartz. Rather a scarce mineral.

Wad.—*Hydrous Oxide of Manganese, Earthy Manganese.*—**Amorphous.** H 6·5 G 2·179 — 3·700. Case 13. Opaque. *Lus.* imperfect, metallic, feeble. *Col.* clove-brown, passing into gray. *Str.* brown, shining. Very sectile, unctuous to the touch.

The Hartz, Franconia, Siegen, Nassau, Carinthia, Piedmont, Mayenne, Arriege, Cornwall and Devonshire. Supposed to afford the colouring matter in dendritic delineations upon limestone, steatite, and other substances.

Crednerite.—*Oxide of Manganese and Copper.*—$Cu\ O + (Mn\ O + Mn^2\ O^3)$ **oblique.** H 4·5 — 5·0 G 4·89 — 5·07. *Frac.* uneven. *Lus.* metallic. *Col.* iron black. *Str.* black. Soluble in hydrochloric acid.

Found at Friedrichrode in Thuringia.

Senarmontite.—$Sb\ O^3$. **cubic.** H 2·5 — 3·0 G 5·22 — 5·30. *Frac.* uneven, lamellar. Transparent-translucent. *Lus.* resinous. Colourless. *Str.* white. B. fusible. Soluble in nitro-muriatic acid.

Found at Sensa in Algiers.

Magnetite.—*Magnetic Iron Ore, Octahedral Iron Ore, Oxydulated Iron.*—$Fe\ O + Fe^2\ O^3$. **cubic.** H 5·5 — 6·5 G 4·96 — 5·20. Case 14. *Frac.* conchoidal, uneven. Opaque. *Lus.* metallic. *Col.* iron black. *Str.* black. B. fusible with great difficulty. Soluble in warm hydrochloric acid, highly magnetic, more so than any other ore of iron.

Found in Norway, Sweden, Lapland, the Ural, the Hartz, Saxony, Bohemia, Corsica, Elba, the Savoy, Spain, New York, New Jersey, Mexico, the Brazils, East Indies, Cornwall, Wicklow. Siberia and the Hartz produce the most powerful natural magnets or loadstones. This ore is distinguished from specular iron by its streak and action on the magnet; it is a very valuable ore, the steel made from its iron being excellent in quality.

Hematite.—*Specular Iron, Red Iron Ore, Rhombohedral Iron Ore, Iron Glance, Oligiste Iron.*—$Fe^2\ O^3$. **rhombohedral.** H 5·5 — 6·5 G 5·0 — 5·3. Case 15. *Frac.* conchoidal, uneven. Opaque, very thin laminæ translucent. *Lus.* metallic. *Col.*

steel-gray, iron black. *Str.* cherry-red, reddish-brown. Brittle. B. infusible. Soluble in warm hydrochloric acid.

Found chiefly in beds and veins in the older rocks. Elba, the Alps, Saxony, Brazils, Salzburg, Cornwall, Lanarkshire, Siberia. A considerable portion of the iron produced in different parts of the globe is obtained from this ore; it requires a greater heat than some other ores, but affords an excellent metal. Ground hematite is used for polishing metals and glass, and also as a colouring substance.

Gothite.—*Prismatic Iron Ore, Hydrous Oxide of Iron, Brown hematite, Pyrrhosiderite Onegite.*—$Fe^2 O^3 + H O$. **prismatic.** H 5·0 — 5·5 G 4·12 — 4·37. Case 16. *Frac.* imperfect, conchoidal. Translucent on the edges. Opaque. *Lus.* adamantine. *Col.* yellowish-brown, reddish-brown, blackish-brown. *Str.* yellowish-brown. Brittle, B. fusible with great difficulty. Soluble in hydrochloric acid.

In veins and cavities. Clifton, Cornwall, Oberstein, Bavaria, Nassau, Saxony, Silesia, Bohemia, Hungary, Russia, Mount Sinai, Brazils. A good iron ore.

Limnite.—*Brown Hematite, Hydrous Oxide of Iron.*—$2 Fe^2 O^3 + 3 H O$ H 5·0 — 5·5 G 3·4 — 3·95. Case 16. Opaque. *Lus.* resinous. *Col.* yellowish-brown, blackish-brown. *Str.* yellowish-brown. Brittle. Soluble in warm hydrochloric acid.

Carinthia, Styria, Hungary, Saxony, Nassau, the Hartz, Black Forest, Bohemia, Silesia, the Pyrenees, Spain, Scotland, Cornwall, Siberia, Brazils, United States.

Turgite.—$2 Fe^2 O^3 + H O$. **massive.** H 5·0 G 3·56 — 3·74. *Frac.* even, conchoidal. Opaque. *Lus.* dull. *Col.* brownish-red. *Str.* blood-red. B. infusible.

Found in copper mines in the Ural and the Altai.

Cuprite.—*Red Oxide of Copper, Ruby Copper, Octahedral Copper Ore.*—$Cu^2 O$. **cubic.** H 3·5 — 4·0 G 5·89 — 6·15. Case 17. *Frac.* conchoidal, uneven. Semi-transparent, translucent on the edges. *Lus.* adamantine. *Col.* cochineal red, lead-gray. *Str.* brownish-red, shining. Brittle. B. reducible. Soluble in nitric acid, and in ammonia.

Found in beds and veins in granite and crystalline slate rocks. The Banat, Siberia, Lyons, Cornwall, Cuba, Spain, Saxony, Norway, Australia, Peru and Chili. When found in sufficient quantity one of the most valuable ores of copper.

Ice.—$H O$ **rhombohedral.** H 1·5 G 0·918 at 0° centigrade. *Frac.* conchoidal. pellucid. *Lus.* vitreous. Sectile, rather brittle.

Hexagonal prisms said to be observed in the levels of the Lorenz Gengentrum mine near Freiberg.

Irite.—$Ir O^3 + Os O^3, Cr O^3$ probably. **cubic.** = 6·056. Case 2. *Lus.* metallic. *Col.* iron black. Insoluble in acids.

In fine scales in cavities of the larger pieces of platinum, and in the ferruginous platinum sand of the Ural.

Periclase—$Mg O$. **cubic.** H 6·0 — G 3·75. Transparent. *Lus.* vitreous. *Col.* dark green. B. infusible. Soluble when in powder in acids.

Found in Monte Somma near Naples.

Brucite.—*Rhombohedral Kuphon Glimmer.*—$Mg O + HO$. **rhombohedral.** H 2·0 G 2·3 — 2·4. *Frac.* scarcely observable. Semi-transparent-translucent. *Lus.* pearly. *Col.* white, sometimes inclining to gray and green. *Str.* white. Sectile. B. infusible. Soluble in acids.

Found in serpentine. New Jersey, New York, Scotland, Siberia.

Wismuthocher.—*Bismuthochre, Oxide of Bismuth.*—$Bi\ O^3$. Soft. G 4·361. Case 17. *Frac.* uneven, earthy. Opaque. *Lus.* adamantine, feeble. *Col.* yellow-gray, variable. B. reducible. Soluble in nitric acid.

Found with bismuth in Saxony, Bohemia, Siberia.

Spartalite.—*Red Oxide of Zinc, Zincite, Spartalite, Red Zinc, Prismatic Zinc Ore.*—Zn O. **Rhombohedral.** H 4·0 – 4·5 G 5·43 — 5·53. Case 17. *Frac.* conchoidal, Translucent on the edges. *Lus.* adamantine; when pure colourless, usually red, inclining to yellow. *Str.* orange-yellow. Brittle. B. infusible. Soluble in nitric acid.

Found in beds with franklinite and calcite in iron mines in New Jersey and near Sparta. Also found distinctly crystallized in the iron and zinc furnaces of Silesia and Liege.

Franklinite.—*Dodecahedral Iron Ore.*—$RO + R^{12}\ O^3$ where R is Fe, Mn, or Zn, and R^1, Fe, or Mn. **cubic.** H 6·0 – 6·5 G 5·07 – 5·13. Case 17. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* dark brown. Brittle. B. infusible. Soluble in warm hydrochloric acid.

Found with spartalite and calcite in New Jersey; with calamine and smithsonite at Altenberg. A rare mineral, distinguished from magnetic iron by its streak.

Asbolane.—*Earthy Cobalt, Black Cobalt Ochre, Black Oxide of Cobalt.*—(Co O or Cu O) $+ 2\ Mn\ O^2 + 4\ HO$. **amorphous.** H 1·0 — 1·5 G 2·2. Case 17. *Frac.* conchoidal. Opaque. *Lus.* resinous, glimmering, dull. *Col.* Bluish and brownish-black, blackish-blue. *Str.* black, shining. Sectile. B. infusible.

Found in Thuringia, Hessia, Black Forest, Lusatia, the Tyrol, Siberia, Cheshire, Howth, near Dublin. Used in the manufacture of smalt.

Pechuran.—*Pitch Blende, Uran Ochre, Uraine, Oxide of Uranium.*—$U\ O + U^2\ O^3$. **cubic.** H 5·5 G 6·4 – 6·71. Case 17. *Frac.* conchoidal, uneven. Opaque. *Lus.* resinous. *Col.* pitch-black, greenish-black, grayish-black. *Str.* greenish-black. Brittle. B. infusible. Dissolves in hot nitric acid.

Found accompanying ores of silver and lead. Saxony, Bohemia, and Cornwall. A valuable ore for the porcelain painter, producing a fine orange colour, and also a black.

Minium.—*Native Minium, Red Oxide of Lead, Mennige.*—$2\ Pb\ O + Pb\ O^2$ H 2·0 – 3·0 G 4·6. Case 18. *Frac.* earthy, even, flat, conchoidal. Opaque. *Lus.* resinous. *Col.* aurora red. *Str.* orange-yellow. B. fusible. Partially soluble in nitric acid.

Found in veins in clay slate. Anglesea, Yorkshire, Siberia; often a produce of the decomposition of other lead ores.

Cassiterite.—*Oxide of Tin, Tin Stone, Pyramidal Tin Ore.*—$Sn\ O^2$. **pyramidal.** H 6·0 – 7·0 G 6·8 – 7·0. Case 18. *Frac.* imperfect, conchoidal. Semi-transparent. Opaque. *Lus.* adamantine. *Col.* colourless, gray, yellow, red, brown-black. *Str.* light-gray, light-brown. Brittle. B. infusible. Not acted upon by acids.

Found in veins and beds. Sumatra, Siam, Pegu, Malacca, Brazils, Cornwall, Bohemia, Saxony, Silesia, Spain, France, Mexico, Chili, Sweden, Russia, North and South America. A valuable tin ore. Upwards of 4000 tons of tin are annually obtained from the mines in Cornwall. It is extensively used for covering vessels of copper and iron; also in the *composition* of pewter, and for mirrors. The muriate of tin is of great value to the dyer *and calico printer.*

Plattnerite.—*Superoxyd of Lead.*—Pb O^2. **rhombohedral.** G 9·392 — 9·448. *Frac.* uneven. Opaque. *Lus.* adamantine. *Col.* iron-black. *Str.* brown. Brittle. B. easily reduced.

Supposed to have been found at Leadhills.

Corundum.—*Rhombohedral Corundum, Corindon.*—AlO^3. **rhombohedral.** H 9·0 G 3·93 — 4·08. Case 19. *Frac.* conchoidal, uneven. Transparent, translucent on the edges. *Col.* white, colourless, red, blue, green, yellow, brown, and gray. B. infusible. Insoluble in acids.

The red varieties are called *rubies* and the blue *sapphires*, and are found in gravel and river sand in Ceylon, Pegu, the Elbe, Bohemia, and Puy in France. The other crystallized varieties are called *corundum*, and *adamantine spar* when of a brown colour, and are found in China, Ceylon, the Carnatic, Mysore, the Ural, Piedmont, Sweden, Lapland, New Jersey, Connecticut, the Rhine. The granular and massive variety called *emery* is found in Saxony, Italy, Spain, and Asia Minor. The red sapphire, or oriental ruby, when perfect in colour and transparency, and of a considerable size, almost rivals the diamond in value. Some of the blue sapphires, cut perpendicularly to the axis of the six-sided prisms, present a bright opalescent star with six rays, and are called *star sapphires*. Emery is used extensively for polishing and cutting gems, stones, and other articles.

Diaspore.—*Euklastic Disthene Spar.*—Al O^3 + H O. **prismatic.** H 5·5 G 3·30 — 3·43. Case 19. *Frac.* conchoidal, uneven. Transparent, translucent. *Lus.* vitreous, pearly. *Col.* colourless, white, green, blue, dark violet, yellowish-brown. *Str.* white. B. infusible.

Found in the Ural, Hungary, St. Gotthardt, Ephesus. An extremely rare mineral distinguished from *kyanite* by its superior lustre.

Hydrargillite.—Al O^3 + 3 H O. **rhombohedral.** H 2·5 — 3·0 G 2·340 — 2·387. Case 19. *Lus.* vitreous, pearly, bright. *Col.* colourless, light reddish-white. B. infusible. Soluble with difficulty in hot sulphuric acid or hydrochloric acid.

The Ural, Brazils, and Massachusetts.

Volknerite.—6 Mg O + Al^3 O^3 + 16 HO. **rhombohedral.** G 2·04. *Lus.* pearly. *Col.* white. Unctuous to the touch. B. infusible. Soluble in acids.

Found at Schischimskaja, in the Ural.

Spinelle.—*Aluminate of Magnesia, Dodecahedral Corundum.*—Mg O + Al O^3. The Mg sometimes replaced by Fe, and the Al by 2 Fe. **Cubic.** H 7·5 — 8·3 G 3·52 — 3·95. Case 19. *Frac.* conchoidal. Transparent, translucent, opaque when black. *Lus.* vitreous. *Col.* white, red, blue, green, yellow, brown, black. *Str.* white. Brittle. B. infusible. Insoluble in hydrochloric acid, partially so in sulphuric acid.

Red and *violet spinelle*, found in alluvial soil and in the sand of rivers. Ceylon, Ava, Mysore. The scarlet is called the *spinelle ruby;* the rose-red, *balas ruby;* the yellow or orange-red, the *rubicelle;* and the violet-coloured, *almandine ruby. Blue spinelle* in granular limestone and dolomite; Sweden, Finland, Moravia, and Ceylon. *Black spinelle*, called *pleonaste;* Ceylon, Bohemia, Montpellier, the Tyrol, Vesuvius, the Ural, New York. *White spinelle*, found with black garnet and green augite, at La Ricia, near Rome. *Grass-green spinelle*, called *chloro-spinelle*, in the chlorite slate of Slatoust, in the Ural. The spinelle ruby is a gem, and when well coloured and large is highly prized. Distinguished from the oriental ruby by being softer, from garnet by its lighter colour, and from red topaz, whose colour has been produced artificially, by its not possessing double refraction.

Gahnite.—*Automalite, Octahedral Corundum.*—Zn O + Al O^3, part of the Zn being replaced by Mg and Fe, and part of the Al by 2 Fe. **Cubic.** H 7·5 — 8·0

G 4·23 — 4·29. Case 19. *Frac.* conchoidal. *Lus.* vitreous. *Col.* dark leek-green, blackish-green, grayish-green, blue, black. *Str.* gray. Brittle. B. infusible. Not acted upon by acids.

Found embedded in talc slate, in Sweden, Finland, Connecticut.

Chrysoberyl.—*Cymophane, Prismatic Corundum.*—$G\,O + Al\,O^3$. **prismatic.** H 8·5 G 3·680 — 3·754. Case 19. *Frac.* conchoidal. Transparent, semi-transparent. *Lus.* vitreous. *Col.* greenish-white, asparagus-green, oil-green, greenish-gray. *Str.* white. B. infusible. Insoluble in acids.

Found in the Ural, Connecticut, New York, Moravia, Ceylon, Pegu, the Brazils. When transparent and cut with facets, it forms a brilliant yellow gem. When it presents its peculiar milky or opalescent appearance, from which it derives the name of *cymophane*, or floating light, it is cut *en cabochon*. *Chrysoberyl* is distinguished from *moon-stone* and *opalescent quartz* by its superior hardness; from *yellow topaz* by not becoming electric when heated.

Wolframocher.—*Oxide of Tungsten.*—$W\,O^3$. **earthy.** Opaque. *Lus.* dull. *Col.* yellow. Soluble in ammonia.

Found at Huntington, in the United States, with wolfram and scheelite.

Coracite.—$U^2\,O^3$. **amorphous.** H 3·0 G 4·378. *Frac.* uneven. *Col.* pitch-black. *Str.* gray. B. infusible. Soluble in hydrochloric acid.

Found on the north shore of Lake Superior.

Plombgomme.—*Hydrous Aluminate of Lead, Plumbo Resinite.*—$(PbO + 2AL^2O^3) + 6HO$. **globular masses.** H 5 G 4·88 — 6·421. Case 19. *Frac.* conchoidal. translucent. *Lus.* resinous. *Col.* yellowish, reddish-brown. *Str.* white. B. fusible. Soluble in concentrated nitric acid.

Found in Brittany, Cumberland, and Missouri, in lead mines. Much resembles some varieties of mammilated blende.

Quartz.—*Rhombohedral Quartz, Rock Crystal.*—SiO^2. **rhombohedral.** H 7·0 G 2·5 — 2·8. Cases 21-24. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* white, colourless, violet, blue, rose-red, brown, green. *Str.* white. B. infusible. Insoluble in all acids except *hydro-fluoric acid.*

Amethyst.—This term is now applied to all the violet, purple, blue, white, yellow, and green crystals of quartz which, when fractured, present the peculiar undulated structure described by Sir David Brewster,—it was formerly restricted to the violet specimens. The finest violet amethysts are found in Siberia, India, Ceylon, and Persia; when uniform in tinge, and transparent, they form a gem of great beauty. Crystals of inferior colour to these are found in Transylvania, Hungary, Saxony, the Hartz, and Ireland. White and yellow crystals from the Brazils, when cut, are frequently substituted for the topaz.

Rock Crystal.—This term is used for the transparent crystals found in Switzerland, Savoy, Dauphiné, Piedmont, Quebec, Bristol, Ireland, &c. When pure, it is cut into lenses for spectacles, called *pebbles*; it is also used for vases and other ornamental purposes.

Smoky Quartz.—Applied to the wine-yellow, clove-brown crystals found in Scotland, Bohemia, Pennsylvania, and the Brazils; also called the Scottish *cairngorum*, and much used as an ornamental stone.

Rose or Milk Quartz.—Massive quartz of a rose-red and milk-white colour, found in Bavaria, Finland, and Connecticut.

Prase.—Quartz, coloured of a dark leek-green by admixture of amphibole, found massive in the iron mines of Saxony.

Siderite.—Indigo or berlin-blue quartz. Saltzburg.

Common Quartz comprehends all the massive varieties of quartz not mentioned above; it is found in great abundance, forming veins in primitive and transition rocks, sometimes many hundred feet in thickness.

Hornstone, Flinty Slate, Lydian Stone, and *Flint*, are names given to the compound varieties of quartz which possess a fine texture.

Float-stone, or *spongiform quartz*, consists of numerous minute white or gray crystals of quartz, which will swim on water, till the air in its numerous cavities is displaced.

Chalcedony is a mixture of crystalline and amorphous quartz, found at Chalcedon, in Asia Minor, Iceland, Faroe Islands, Hungary, Western Islands, Cornwall, India, and Siberia. The red, brown, and yellow varieties are called *carnelians;* the yellow are known to lapidaries as *sarde*, Most oriental cornelians are originally dark gray, and owe their fine red hue to an artificial exposure to heat; found in Arabia, India, Surinam, Saxony, and Scotland.

Agates are composed of irregular layers of chalcedony of various colours.

Mocha-stone and *moss-agates*, are transparent varieties,

The *onyx* is formed of chalcedony, arranged in alternate layers of different colours.

Catseye is chalcedony of a brownish-red or greenish-gray colour, penetrated by amianthus, and exhibiting a play of light; found in Ceylon and Malabar.

Chrysoprase is of an apple-green colour, produced by oxide of nickel; found in Silesia and Vermont.

Avanturine contains many minute fissures or else scales of mica, which reflect bright points of light, and give polished specimens a shining spangle-like appearance; found in Spain and India.

Plasma, a transparent chalcedony of a grass-green or leek-green colour; found in India and China.

Heliotrope, or *blood-stone*, chalcedony coloured by a green earth, and containing spots of yellow or blood-red jasper; found in Bucharia, Tartary, Siberia, and the Hebrides.

Iron-flint, *Eisenkiesel*, or *ferruginous quartz*, contains five per cent. of iron; is found in Saxony, Bohemia, and Hungary.

Jasper is rendered opaque by a mixture of iron and clay. The *striped jasper*, from Siberia, Saxony, and Devonshire, is distinguished by its ribbon-like delineations; the Egyptian jasper, by its red and brown colours and globular structure.

Fig. 395.

Fig. 396.

Fig. 395 is a crystal of quartz in the British Museum, which shows most beautifully the gradual growth of crystals; a transparent hexagonal crystal, terminated by its planes, similar to Fig. 395 or Fig. 396, was first formed of pure quartz, a deposit of green chlorite then took place on its terminal planes, the crystal was then increased by fresh accessions of silica, still retaining its proper crystalline form, when, after it had considerably increased, another sprinkling of chlorite fell upon its terminal planes; this seems to have been repeated four times. The crystal being very transparent, the chlorite reveals most distinctly four successive stages of its formation. Fig. 396 is a specimen of Egyptian jasper in the British Museum, which is remarkable on account of the natural markings of its fractured surface representing a very tolerable likeness of Chaucer, the poet.

Many agate, onyx, and cornelian cylinders were brought from the ruins of Nineveh, by Mr. Layard.

The moss agates, heliotropes, and flints, from the upper beds of chalk, contain marine organisms, principally sponges.

Opal.—*Resinous Quartz, Uncleavable Quartz.*—**Amorphous.** H 5·5 — 6·5 G 1·9 — 2·3. Case 24. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellow, red, brown, green, gray, black. Some varieties exhibit a beautiful play of colours. Very brittle.

Hyalite, or *Muller's glass* appears in small uniform, botryoidal, and sometimes stalactitic shapes, either of a white colour or transparent; found in amygdaloid and in clinkstone. Frankfort, Hungary, and Bohemia.

Fire opal, or *girasol* of the French, possesses bright hyacinth red and yellow tints; found in Mexico and the Faroe Islands.

Noble opal, or *precious opal*, includes all those specimens which exhibit the play of prismatic colours; these are found embedded in porphyry at Czervenitza in Hungary and at Honduras in America, also in Mexico and in Iceland. When large and pure, it is considered a gem of great value.

Common opal and *semi-opal* are devoid of the play of colours, and are distinguished by their different degrees of transparency, lustre, and perfection of their conchoidal fracture; found in porphyry and in the cavities of amygdaloid rocks, Hungary, Faroe, Iceland, Giant's Causeway, and the Hebrides.

Cacholong, nearly opaque, contains a small portion of alumina, and adheres to the tongue; Bucharia, Faroe, Iceland, and Giant's Causeway.

Hydrophane is a variety of opal which is opaque when dry, but transparent when immersed in water; Saxony.

Wood opal is distinguished by its ligneous structure and semi-transparency; found in Hungary, Transylvania, Bohemia, Faroe, and New South Wales.

Siliceous sinter, a deposit from hot springs; the Geyser, in Iceland.

Pearl sinter, or *fiorite*, found in the cavities of volcanic tufa.

Wollastonite.—*Tabular Spar, Prismatic Augite Spar.*—$CaO + Si\,O^2$. **oblique.** H 5·0 G 2·8 — 2·9. Case 25. *Frac.* uneven. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* white, passing into gray, yellow, red, and brown. *Str.* white. Rather brittle. B. fusible with difficulty. Soluble in hydrochloric acid, leaving a jelly of silica.

Found in granular limestone, lava, gneiss, and trap. The Banat, Finland, Sweden, Vesuvius, Canada, United States, Saxony, Ceylon, and Edinburgh. Can be formed artificially by fusing lime and silica.

Okenite.—*Dysclasite.*—$Ca\,O + 2Si\,O^2 + 2HO$. **prismatic.** H 4·5 — 5·0 G 2·28 — 2·36. Case 28. Translucent. *Lus.* pearly. *Col.* yellowish, white, bluish-white. B. fusible. Gelatinizes in hydrochloric acid.

Found in amygdaloid rock. Faroe, Iceland, and Greenland.

Soapstone.—*Steatite.*—$6MgO + 5SiO^3 + 2HO$. **massive.** H 1·5 G 2·266. Case 25. *Frac.* uneven. Translucent on edges. *Lus.* dull. *Col.* yellowish and grayish-white, bluish-gray. *Str.* shining, unctuous. B. fusible. Soluble in sulphuric acid.

Found in serpentine, limestone, &c. Cornwall, Bayreuth, Greenland, St. Helena, China. Used in the manufacture of fine porcelain, for fulling, marking cloth and glass, polishing mirrors and marble, diminishing the friction of machinery, and as a fire-stone for furnaces.

Ottrelite.—*Phyllite.*—$3(1FeO + SiO^2) + (2AlO^3 + 3SiO^2) + 3HO$. Scratches glass. G 4·4. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* grayish-black, inclining to green. *Str.* grayish-white. B. fusible. Soluble in hot sulphuric acid.

Found in small hexagonal crystals in clay slate. Ottrez Luxembourg, and Massachusetts.

Meerschaum.—*Earthy Carbonate of Magnesia, Magnesite, Sepiolite, Keffekil.*—$MgO + SiO^3 + HO$? H 2·5 G 1·2 — 1·6. Case 25. *Frac.* earthy. Opaque. *Lus.* dull. *Col.* white, inclining to yellow, red, or gray. *Str.* shining. Adheres to the tongue.

Found in nodules in Greece, Spain, Portugal, Moravia, Sweden, Asia Minor. Used for pipe-bowls. Derives its name, which signifies *froth of the sea*, from its lightness and whitish colour.

Lithomarge.—*Steinmark.*—H 2·5 G 2·496. Case 25. *Frac.* conchoidal. Opaque. *Lus.* dull. *Col.* blue, passing into red and gray. *Str.* shining. Sectile. Adheres to the tongue. B. infusible.

A silicate of alumina and iron, found at Planitz in Saxony.

Serpentine.—*Ophite, Marmolite, Retinalite, Chrysotile, Metaxite, Baltimorite, Picrolite.*—$2(MgO + SiO^2) + (MgO + 2HO)$. H 3·0 G 2·47 – 2·60. Case 25. *Frac.* uneven, conchoidal. Translucent, opaque. *Lus.* resinous, dull. *Col.* green, of various shades. *Str.* white, shining. B. fusible on the edges. Decomposed in powder by hydrochloric and sulphuric acids.

Occurs in masses forming rocks, in beds and veins, and pseudomorphous. Saxony, Bohemia, Moravia Austria, Styria, Saltzburg, the Tyrol, Hungary, Silesia, Italy, Corsica, Norway, Sweden, Siberia, United States, England, and Scotland. The term *noble* is applied to those serpentines which are of a uniform green colour, and are translucent and fit for cutting. Serpentine is easily cut or turned, and admits of a high polish; it is used for vases, architectural decorations, and other ornamental purposes. It derives the name of *serpentine*, or *ophite*, from its spotted or variegated appearance like the skin of a snake.

Antigorite.—$3(RO + SiO^2) + (MgO + HO)$ where R is Mg and Fe. H 2·5 G 2·62. Case 25. Transparent, translucent. *Lus.* feeble. *Col.* green. *Str.* white. B. fusible on the edges. Decomposed by sulphuric acid.

Found in the valley of Antigorio in Piedmont.

Villarsite.—Prismatic. Soft. G 2·978. Case 25. *Frac.* granular. Translucent. *Col.* yellowish-green. B. infusible. Decomposed by strong acids.

Found in a bed of magnetite in Piedmont, supposed to be an altered olivine.

Bronzite.—*Hemiprismatic Schiller Spar, Diallage.* $RO + SiO^2$, where R is Mg and Fe. **oblique.** H 5·0 — 6·0 G 3·2 — 3·6. Case 25. Translucent. *Lus.*

metallic, pearly, frequently resembling bronze. *Col.* dark-green, brown, ash-gray. *Str.* grayish. Slightly brittle. B. fusible with difficulty. Not soluble in acids.

Found in serpentine and basalt. Styria, Bayreuth, Moravia, Cornwall, the Tyrol, Hessia, Silesia, Spain.

Clintonite. — *Xanthophyllit, Chrysophane, Seybertite, Holmesite, Brandisite.* **rhombohedral.** H 4·5 — 6·5 G 3·01 — 3·10. Case 25. *Lus.* vitreous. *Col.* yellow, brown, green. B. infusible. Decomposed by strong hydrochloric acid.

Found in the Ural, Tyrol, and New York.

Olivine.—*Chrysolite, Peridot, Prismatic Chrysolith, Hyalosiderite.*—$2\ MgO + SiO^2$. **prismatic.** H 6·5 — 7·0 G 3·3 — 3·44. Case 25. *Frac.* conchoidal, transparent, translucent. *Lus.* vitreous. *Col.* green, yellow, brown. *Str.* white. Decomposed by sulphuric acid, forming a jelly.

Found in Egypt, Natolia, the Brazils, Styria, Vesuvius, Mexico, Sweden, Baden. The transparent varieties are called chrysolite, the brown hyalosiderite. Chrysolite is prized as a gem when large, free from flaws and of a good colour; it is so soft as to lose its polish unless worn with care. Chrysolite is softer than chrysoberyl, harder and heavier than apatite, and distinguished from the green tourmaline by infusibility and absence of electrical properties when heated. *Chrysolite* is derived from χρυσος gold, and λιθος stone; and *hyalosiderite* from ὕαλος glass, and σιδηρος iron.

Picrosmine.—*Prismatic picrosmine steatite.*—$2\ MgO + SiO^2 + HO$. **prismatic.** H 2·5 — 3·0 G 2·59 — 2·66. *Frac.* uneven, opaque. *Lus.* pearly. *Col.* greenish-white, blackish-green. *Str.* white, very sectile. B. infusible.

Found in masses in Bohemia, the Tyrol, and Saxony; distinguished from asbestos by the bitter argillaceous odour it exhales when moistened; hence its name from πικρὸς bitter, and οσμη smell.

Batrachite.—$(2\ Ca\,O + Si\ O^2) + (2\ Mg\ O + Si\ O^2)$. crystalline system undetermined. H 5·0 G 3·033, Case 25. *Frac.* imperfect, conchoidal. Translucent. *Lus.* resinous. *Col.* light greenish-gray, white. *Str.* white. B. fusible.

Found at Rizoni in the Tyrol.

Monticellite.—$(2\ CaO + Si\ O^2) + (2\ Mg\ O + Si\ O^2)$. **prismatic.** H 5·5 G. 3·245 — 3·275. Case 25. Nearly transparent. *Lus.* vitreous. *Col.* colourless, yellowish. Soluble in hydrochloric acid.

Found in granular limestone at Monte Somma. Named after the Neapolitan mineralogist Monticelli.

Smithsonite.—*Prismatic Zinc Baryte, Prismatic or Electric Calamine, Siliceous Oxide of Zinc, Zinkglas, Galmei.*—$2\ Zn\ O + Si\ O^2 + HO$. **prismatic.** H 5·0 G 3·35 — 3·50. Case 26. *Frac.* uneven, transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellow, brown, green, blue. *Str.* white. Brittle. Becomes electric when heated. B. infusible. Soluble in acids, leaving a jelly of silica.

Found in veins. Aix-la-Chapelle, Liege, Carinthia, Silesia, Poland, Gallicia, Baden, Derbyshire, Cumberland, Scotland, the Tyrol, Hungary, the Banat, Spain, Siberia, the Hartz. Used as an ore of zinc.

Willemite.—*Siliceous Oxide of Zinc, Brachytype Zinc Baryta, Troostite.*—$2\ Zn\ O + Si\ O^2$. **rhombohedral.** H 5·5 G 3·89 — 4·18. Case 26. *Frac.* imperfect conchoidal, semi-transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellow, brown. *Str.* white. Brittle. B. fusible on the edges. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found at Moresnet, Stolberg, Carinthia, Servia, and New Jersey.

Rhodonite. — *Siliciferous Oxide of Manganese, Diatomous Augite Spar.*— Mn O + Si O^2. **oblique.** H 5·0 — 5·5 G 3·61 — 3·65. Case 26. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* red, brown, spotted with green. *Str.* reddish-white. B. fusible. Insoluble in hydrochloric acid.

Found in masses. Sweden, Transylvania, the Hartz, New Jersey, Piedmont, Algiers, Cornwall. *Allagite, photizite,* and *corneous manganese*, are all varieties of *Rhodonite.*

Tephroite.—2 Mn O + Si O^2. Crystalline system undetermined. H 5·5 G 4·06 — 4·12. Case 26. *Frac.* uneven. *Lus.* adamantine. *Col.* ash-gray, tarnish brown or black. *Str.* ash-gray. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found with franklinite at Franklin in New Jersey.

Cererite.—*Rhombohedral Cerium Ore, Siliciferous Oxide of Cerium, Cerite, Red Siliceous Oxide of Cerium.*—RO + Si O^2 + 2 HO, where R represents cerium, lanthanium, and didymium. **rhombohedral.** H 5·5 G 4·9 — 5·0. Case 26. *Frac.* uneven, translucent on edges. Opaque. *Col.* brown, red, gray. *Str.* grayish-white. Brittle. B. infusible. Soluble in hydrochloric acid, leaving a jelly of silica.

Found only in an old copper mine at Bastnäs, in Sweden. Resembles red granular corundum, but easily distinguished from it by its inferior hardness.

Tritomite.—Cubic. H 5·5 G 4·16 — 4·66. *Frac.* conchoidal. Opaque. *Lus.* vitreous. *Col.* dark-brown. *Str.* yellowish-brown. Very brittle. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found at Lamö in Norway in syenite.

Chlorophæite.—Soft. G 2·02. Case 26. Dull green, and afterwards black. B. infusible. Decomposed by hydrochloric acid.

Found imbedded in amygdaloid rock in the island of Rum, and in Fife.

Chloropal.—*Nontromite, Pinguite.*—Fe^2 O^3 + 2 Si O^3 + 3 HO. Massive. H 3·0 — 4·0 G 2·0. Case 26. *Frac.* conchoidal. Opaque. Translucent on the edges. *Col.* greenish-yellow and pistachio green. *Lus.* vitreous, dull. Brittle. B. infusible.

Found in Hungary and the Hartz.

Stilpnomelane.—Rhombohedral. H 3·0 — 4·0 G 3·0 — 3·4. Case 26. Opaque. *Lus.* vitreous. *Col.* black, blackish-green. *Str.* olive-green. Rather brittle. B. fusible. Imperfectly decomposed by acids.

Found in clay slate in Silesia; derives its name from στιλπνος shining and μελας black.

Hisingerite.—*Thraulite, Gillingite, Polyhydrite.*—**Reniform masses.** H 3·0 G 2·79 — 3·05. Case 26. *Frac.* conchoidal. Opaque. *Lus.* resinous. *Col.* black. *Str.* yellowish-brown. Brittle. B. fusible. Partially soluble in hydrochloric acid.

Found in Bavaria and Sweden.

Cronstedtite.—*Sideroschizolite, Rhombohedral Melane Mica.*—2 Fe^2 O^3 + Si O^2 + 2 (2 Fe O + Si O^2) + 5 H O. Reniform and fibrous masses. H 2·5 G 3·348.

Case 26. Translucent. Opaque. *Lus.* vitreous. *Col.* black. *Str.* dark green. Brittle. B. infusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in Bohemia, Cornwall, Brazils, and Chili.

Fayalite.—*Iron Chrysolite.*—$2\ Fe\ O + Si\ O^3$. **prismatic.** H 6·5 G 4·11 – 4·14. Case 26. *Frac.* imperfect, conchoidal. Opaque. *Lus.* imperfect, metallic. *Col.* iron-black, inclining to green or brown, brass-yellow tarnish. Magnetic. B. fusible.

Found on the sea-shore at Fayal, and on one of the Morne mountains, Ireland. Crystals having the composition of Fayalite and the form of Olivine, are found in refining cinders and the slag of copper furnaces.

Anthosiderite.—$Fe^2\ O^3 + 4\ Si\ O^2 + H\ O$. **fibrous.** H 6·5 G 3·0. Case 14. Opaque. *Lus.* silky. *Col.* yellow ochre and brown. *Str.* the same. Very tough. B. fusible. Decomposed by hydrochloric acid.

Found with magnetite in the Brazils; derives its name from ανθος a flower and σιδηρος iron.

Palagonite.—Amorphous. H 3·0 – 4·5 G 2·40 – 2·43. *Frac.* conchoidal. Transparent, translucent. *Lus.* waxy. *Col.* yellow, brown. *Str.* yellow. B. fusible. Decomposable by hydrochloric acid.

Found in volcanic tufa, in Sicily and Iceland.

Chrysocolla.—*Hydrosiliceous Copper, Copper-green, Uncleavable Staphyline Malachite, Kiessel Malachite.*—$Cu\ O + Si\ O^2 + 2\ H\ O$. **amorphous.** H 2·0 – 3·0 G 2·0 – 2·2. Case 26. *Frac.* conchoidal. Semi-transparent. *Lus.* resinous. *Col.* green, sky-blue. *Str.* greenish-white. Slightly brittle. B. infusible. Decomposed by nitric or hydrochloric acid.

Found, with other ores of copper, in the Banat, Hungary, the Tyrol, Bohemia, Saxony, the Ural, Altai, Spain, Norway, New Jersey, Cornwall, Mexico, Chili, Australia.

Dioptase.—*Rhombohedral Emerald Malachite, Emerald Copper Achirite, Kupfersmaragd.*—$CuO + SiO^2 + HO$. **rhombohedral.** H 5·0 G 3·27 – 3·348. Case 26. *Frac.* conchoidal, uneven Transparent, translucent. *Lus.* vitreous. *Col.* emerald-green. *Str.* green. Brittle. B. infusible. Soluble in nitric and hydrochloric acids, leaving a jelly of silica.

Found in limestone in the Kirghese Steppes, in Siberia. Derives its name from δια through, and 'οπτομαι to see, in allusion to the possibility of seeing the natural joints by transmitted light. Distinguished from the emerald by inferior hardness, higher specific gravity, and by acquiring negative electricity by friction.

Eulytine.—*Bismuth Blende, Silicate of Bismuth.*—$2BiO^3 + 3SiO^3$. **cubic.** H 4·5 – 5·0 G 5·965. Case 26. *Frac.* uneven. Semi-transparent. Opaque. *Lus.* adamantine. *Col.* brown or yellow. *Str.* yellowish-gray. Brittle. B. fusible. Soluble in hydrochloric acid, leaving a jelly of silica.

Found in minute crystals in cobalt veins. Schneeberg and Braünsdorf in Saxony.

Zircon.—*Pyramidal Zircon, Hyacinth.*—$ZrO + SO^2$. **pyramidal.** H 7·5 G 4·0 – 4·7. Case 26. *Frac.* conchoidal, uneven. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* red-brown, yellow, gray, green, white. *Str.* white. B. infusible. Partially decomposed by sulphuric acid.

The term *hyacinth* is applied to transparent and bright-coloured varieties, *Jargoon* to crystals devoid of colour and of a smoky tinge, occasionally sold as inferior diamonds;

Zirkonite to the gray and brown, rough and opaque varieties. Found in gneiss, granite, volcanic matter, alluvium, and sand of rivers. Ceylon, Norway, Siberia, New Jersey, Sweden, Greenland, Egypt, Carinthia, France, Italy, Vesuvius, the East Indies, Saxony, the Ural, Transylvania.

Ostranite is a grayish-brown zircon from Fredricksvärn.

Malacone and *Oerstedtite*, names given to two minerals having the form of zircon, and supposed to be that mineral in a stage of decomposition.

Thorite.—$2ThO + SiO^3 + 2HO$. **massive.** H 4·5 G 4·63. Case 26. *Frac.* conchoidal. *Lus.* vitreous. *Col.* black. *Str.* dark-brown. Brittle. B. infusible. Gelatinizes in hydrochloric acid.

Found with mesotype, at Lövö in Norway. It was from this mineral Berzelius first obtained the rare metal *thorium*.

Andalusite.—*Prismatic Andalusite.*—$AlO^3 + SiO^3$. **prismatic.** H 7·5 G 3·1 – 3·2. Case 26. *Frac.* uneven, flat, conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* reddish, passing into pale gray. *Str.* white. B. infusible. Slightly affected by acids.

Found in granite, gneiss, and mica slate. Spain, the Tyrol, Bavaria, Bohemia, Moravia, Silesia, Saxony, France, Siberia, Brazils, Banffshire, Ireland, Connecticut, Massachusetts. Distinguished from *felspar* by its hardness and infusibility, from *corundum* by its structure and specific gravity.

Chiastolite, or *hollow spar*, appears to be a variety of *andalusite*, having prisms of a darker substance in the centre and sometimes in each angle, connected by thin plates of the same. H 5·0 — 5·5 G 2·9 — 2·95. Derives its name from the summits of its crystals being marked in the form of the Greek letter X. Found in the Pyrenees, Spain, Normandy, Cumberland, Wicklow.

Kyanite.—*Disthène*, *Sillimanite*. *Bucholzite*, *Fibrolite*, *Prismatic Disthene Spar*, *Monrolite*, *Rhœtizit.*—$AlO^3 + SiO^3$. **anorthic.** H 5·0 — 6·0 G 3·58 — 3·62. Case 26. *Frac.* uneven. Transparent, translucent. *Lus.* pearly, vitreous. *Col.* blue, white, gray, black, colourless. *Str.* white. Brittle. B. infusible. Insoluble in acids.

Found in mica slate, granite, gneiss, &c. Switzerland, Styria, Carinthia, Banffshire, United States, Bohemia, South America, Massachusetts, the Tyrol, Shetland. Distinguished from *actinolite* by its infusibility, cleavage, and specific gravity. When blue and transparent, is cut and polished as an ornamental stone, resembling *sapphire*.

Bamlite.—H 6·5 — G 2·984. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* white, inclining to green.

Found in slender prisms and crystalline masses, with quartz, in Norway.

Worthite.—$4\ AlO^3 + 5\ SiO^3 + 2\ HO$. Granular aggregations. H 7·0 — 7·5 G 3·0. Case 26. Feebly translucent. *Lus.* pearly. *Col.* white. B. infusible. Insoluble in acids.

Found in the neighbourhood of St. Petersburg.

Allophane.—*Riemanite.*—$3\ Al^2\ O^3 + 2\ Si\ O^3 + 15\ H\ O$. Reniform and botryoidal masses. H 3·0 G 1·852 — 1·889. Case 26. *Frac.* flat, conchoidal, semitransparent. Translucent on the edges. *Lus.* waxy. *Col.* white, yellow, red, brown, blue and green. Brittle. B. infusible. Gelatinizes with acids.

Found in Saxony, Moravia, and Bohemia. Derives its name from ἄλλος and φαίνω to appear, from its change of appearance under the blowpipe.

Halloysite.—*Lenzinite*, *Smectite.*—A hydrous silicate of alumina. H 1·5 — 2·5

G 1·92 — 2·12. Case 26. *Frac.* conchoidal. Opaque. *Lus.* waxy. *Col.* white, blue, green, yellow. B. infusible. Gelatinizes with sulphuric acid.

Found in reniform masses. Silesia, France, New Granada.

Collyrite.—*Scarbroite.*—A hydrous silicate of alumina. H 1·0 — 2·0 G 2·06 — 2·11. Case 26. *Frac.* earthy. Opaque. *Lus.* dull. *Col.* white, reddish, greenish. *Str.* shining. Unctuous to the touch. B. infusible.

Found in reniform masses in the Pyrenees.

Bole.—A silicate of alumina and iron. H 1·5 — 2·5 G 1·6 — 2·0. Case 26. *Frac.* conchoidal. Opaque. *Col.* brown. *Str.* resinous. Sectile.

Found in nodules. Silesia, Bohemia, Saxony, Hebrides.

Schrotterite.—4 $Al^2 O^3 + Si O^3 + 3 H O$. Amorphous. H 3·0 — 3·5 G 1·985—2·015. Case 26. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* light emerald green. *Str.* white. Brittle. B. infusible. Gelatinizes with hydrochloric acid.

Found in nodules in Styria.

Miloschine.—*Serbian.*—$Al O^3 + Si O^2 + 3 H O$. Massive. H 1·5 — 2·0 G 2·131. *Frac.* conchoidal. *Lus.* glimmering dull. *Col.* blue-green. B. infusible. Partially decomposed by hydrochloric acid.

Found massive in Servia.

Groppite.—Crystalline masses. H 2·5 G 2·73. *Frac.* splintering. Semi-transparent in thin fragments. *Col.* Rose-red, brown, red. *Str.* light. Brittle. B. fusible on the edges.

Dillnite.— H 3·5 G 2·835. *Frac.* conchoidal. Opaque. *Lus.* dull. *Col.* white. Case 26.

Found in veins of limestone at Schemnitz in Hungary.

Agalmatolite.—*Figure stone, Talcglaphique, Bildstein.*—H 3·0 G 2·75 — 2·85. Case 26. *Frac.* uneven. *Col.* white, pale gray, green, yellow, flesh red. *Str.* white and shining. Slightly brittle, almost sectile. B. fusible on the thinnest edges. Decomposed by hot sulphuric acid.

Found in China, Saxony and Hungary. Carved by the Chinese into grotesque figures and ornaments.

Apophyllite.—*Pyramidal Kouphone Spar, Oxhaverite, Pyramidal Zeolite, Ichthyopthalmite, Tessalite, Alvine.*—3 $(Ca O, K O, H O) + 2 Si O^3 + 2 H O$. **pyramidal.** H 4·5 — 5·0 G 2·35 — 2·39. Case 27. *Frac.* imperfect, conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, yellow, blue, red, green. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in cavities of amygdaloid rocks, in veins in transition slate, and in beds of magnetite. The Banat, the Tyrol, Iceland, the Hartz, Hindostan, Bohemia, Sweden, Greenland, Siberia, North America, Fifeshire. *Apophyllite* derives its name from απο and φυλλον a leaf, on account of its tendency to exfoliate under the blowpipe. The peculiar pearly lustre of the crystallized varieties, which is one of the most decided characteristics of this mineral, gave rise to the name *ichthyopthalmite*, or fish eye-stone, from ιχθυς a fish and οφθαλμος an eye.

Chabasie.—*Rhombohedral Kouphone Spar, Phacolite, Rhombohedral Zeolite.*—$(Ca O + Si O^2) + (Al O^3 + 3 Si O^2) + 6 H O$. **rhombohedral.** H 4·0 — 4·5 G 2·08 — 2·15. Case 27. *Frac.* uneven. Semi-transparent, semi-translucent. *Col.* colourless, white, reddish, yellowish. *Str.* white. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities and veins in amygdaloid and plutonic rocks. Bohemia, the Tyrol, Faroe, Iceland, Greenland, Sweden, Ireland, Renfrewshire, Hungary, Siberia, Massachusetts.

Mesotype.—*Zeolith, Natrolith, Bergmannite, Mesolite, Radiolite, Peritomous Kouphone Spar.*—($Na\,O + Si\,O^2$) + ($Al\,O^3 + 2\,Si\,O^2$) + $H\,O$. **prismatic.** H 5·0 – 5·5 G 2·24 – 2·26. Case 27. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, gray, yellow, red, pale green. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in basalt, syenite, and transition rocks. Greenland, Iceland, Bohemia, the Tyrol, Ireland, Norway.

Scolezite.—*Needlestone, Poonahlite, Antrimolite.*—($Ca\,O + Si\,O^2$) + ($Al\,O^3 + 2\,Si\,O^2$) + $3\,H\,O$. **oblique.** H 5·0 — 5·5 G 2.2 — 2·3. Case 28. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, reddish, yellowish. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities of amygdaloid rocks. Staffa, Faroe, Iceland, Greenland, Hindostan, the Tyrol, Ireland. Curls up before the blowpipe, whence its name from σκωληξ a worm.

Comptonite.—*Thomsonite, Orthotomous Kouphone Spar.*—3 ($Al\,O^3 + Si\,O^2$) + 3 ($Ca\,O + Si\,O^2$) + $7\,H\,O$. **prismatic.** H 5·0 — 5·5 G 2·31 — 2·38. Case 27. *Frac.* imperfect, conchoidal. Transparent, translucent. *Col.* white, yellow, red. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in amygdaloid rocks. Vesuvius, Hessia, Bohemia, Greenland, Iceland, the Tyrol, Scotland.

Gmelinite.—*Hydrolite, Sarcolite, Heteromorphous Kouphone Spar, Herschelite.*—($R\,O + Si\,O^2$) + ($Al\,O + 3\,Si\,O^2$) + $6\,H\,O$, where R is K, Ca, and Na. **rhombohedral.** H 4·5 G 2·04 — 2·12. Case 27. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* white, reddish. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities of amygdaloid rocks. Vicentine, Ireland, Sicily.

Levyne.—*Macrotypous Kouphone Spar.*—($Ca\,O + Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + $6\,H\,O$. **rhombohedral.** H 4·0 G 2·1 — 2·2. Case 27. *Frac.* imperfect, conchoidal. Semi-transparent. *Lus.* vitreous. *Col.* white, grayish. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities in trap. Ireland, Renfrewshire, Faroe, Iceland, Skye.

Gyrolite.—*Gurolite.* $2\,Ca\,O + 3\,Si\,O^2 + 3\,HO$. H 3·0 – 4·0. Case 28. *Lus.* vitreous, thin plates, transparent. *Col.* white. Very tough. B. fusible.

Occurs in small spherical concretions in the cavities of basalt, from Storr in Skye.

Edingtonite.—*Pyramidal Brythine Spar, Hemi-pyramidal Spar.* **Pyramidal.** H 4·0 – 4·5 G 2·71. Case 28. *Frac.* imperfect, conchoidal. Semi-transparent, translucent. *Col.* grayish-white. *Str.* white. Brittle. B. fusible. Forms a jelly in hydrochloric acid without being completely decomposed.

Found in small crystals in amygdaloid. Dumbarton, Scotland.

Algerite.—Oblique. H 3·0 — 3·5 G 2·697 — 2·948. Translucent. Opaque. *Lus.* vitreous. *Col.* yellowish-white. *Str.* light-brown. B. fusible. Slightly acted on by hydrochloric acid.

Found in white limestone. Franklin, New Jersey.

Analcime,—*Hexahedral Kouphone Spar.*—($Na\,O + Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + 2 HO. **cubic.** H 5·5 G 2·22 — 2·28. Case 28. *Frac.* uneven, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, reddish-white. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities of amygdaloid rocks, in beds of magnetite, gneiss, porphyry. The Tyrol, Scotland, Ireland, Bohemia, the Ural, Faröe, Iceland, Norway, the Hartz.

Eudnophite.—($Na\,O + Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + HO. **prismatic.** H 5·5 G 2·27. *Frac.* even. Transparent. *Lus.* pearly. *Col.* white, gray, brown. *Str.* white. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in syenite. Lamö, near Brevig.

Stilbite.—*Desmin Prismatoidal Kouphone Spar.*—($Ca\,O + 3\,Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + 6 HO. **prismatic.** H 3·5 – 4·0 G 2·1 – 2·2. Case 28. *Frac.* uneven. Semi-transparent. *Lus.* vitreous. *Col.* colourless, white, yellow, red, brown. *Str.* white. Brittle. B. fusible. Decomposed by acids.

Found in cavities of amygdaloidal rocks, also in beds and veins in granite and slate. Iceland, Faröe, Skye, Hindostan, the Tyrol, Norway, Sweden, Silesia, the Hartz, the Alps, Scotland, Siberia.

Epistilbite.—*Diplogenous Kouphone Spar.*—($Ca\,O + 3\,Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + 5 HO. **prismatic.** H 3·5 – 4·0 G 2·24 – 2·25. Case 28. *Frac.* uneven, transparent. *Lus.* vitreous. *Col.* colourless, white. *Str.* white. B. fusible. Decomposed by strong hydrochloric acid.

Found in cavities of amygdaloidal rocks. Iceland, Faröe.

Heulandite.—*Hemiprismatic Kouphone Spar.*—($Ca\,O + 3\,Si\,O^2$) + ($Al\,O^3 + 3\,Si\,O^2$) + 5 HO. **oblique.** H 3·5 – 4·0 G 2·18 – 2·22. Case 28. *Frac.* uneven, transparent. *Lus.* vitreous. *Col.* colourless, white, gray, brown, red. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in cavities of amygdaloidal rocks. Iceland, Faröe, Hindostan, Nova Scotia, Bohemia, the Tyrol, Transylvania, Norway, the Hartz, Saxony, Siberia, Scotland, Skye.

Brewsterite. — *Megalagonous Kouphone Spar.* — **Oblique.** H 5·0 – 5·5 G 2·12 — 2·20. Case 28. *Frac.* uneven. Brittle. B. fusible with difficulty. Decomposed by hydrochloric acid.

Found in cavities of amygdaloidal rocks. Scotland, Ireland, France, and the Pyrenees.

Laumonite. — *Leonhardite, Diatomous Kouphone Spar, Di-prismatic Zeolite.*— ($CaO + SiO^2$) + ($AlO^3 + 3SiO^2$) + 4HO. **oblique.** H 3·5 G 2·33 — 2·41. Case 28. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* yellowish and grayish-white, flesh-red. *Str.* white. Very brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities of amygdaloid, and in metallic veins. Bretagne, Bohemia, the Tyrol, Hungary, Sweden, the Ural, North America, Faröe, Iceland, Skye, Ireland, Scotland. Specimens of this mineral ought to be covered with a thin solution of gum arabic, to counteract the rapid decomposition which takes place when they are exposed to the air.

Prehnite.—*Axotomous Triphane Spar, Koupholite, Edelith, Chiltonite.*—2(CaO + SiO^2) + (AlO^3 + SiO^2) + HO. **prismatic.** H 6·0 – 7·0 G 2·92 – 3·01. Case 29. *Frac.* uneven. Semitransparent, translucent. *Lus.* vitreous. *Col.* green, yellow, gray. *Str.* white. Brittle. Becomes electric by the application of heat. B. fusible. Partially soluble in hydrochloric acid.

Found in granite and crystalline rocks. Dauphiné, the Tyrol, Pyrenees, Switzerland, Saxony, the Hartz, Norway, Sweden, Massachusetts, South Africa, Scotland, Gloucestershire, Staffordshire, Land's End, China. The grass-green varieties have been mistaken for chrysolite, chrysoprase, and emerald.

Nephrite.—*Jade, Uncleavable Nephrite Spar, Beilstein.*—(CaO + SiO^3) + ($3MgO$ + $2SiO^3$). H 5·5 — 6·0 G 2·65 – 3·0. Case 29. *Frac.* splintery. Translucent on the edges. *Lus.* resinous, dark. *Col.* leek-green, greenish-white, greenish-gray. *Str.* white, shining. Tough. Slightly unctuous to the touch. B. fusible on the edges.

Found massive and in blocks with slate and limestone. India, Turkey, Leipsig, Little Thibet, China, Egypt, the Amazon. Vessels made from Jade are as sonorous as porcelain. It is wrought into hatchets by the New Zealanders. Derives its name from *νεφρος a kidney*, because it was supposed to be a remedy for diseases of that organ.

Harmotome.—*Paratomous Kouphone Spar, Staurolite, Pyramidal Zeolite or Cross stone, Morvenite, Andreolite, Andreasbergolite.*—(BaO + $2SiO^2$) + (AlO^3 + $3SiO^2$) + 5HO. **prismatic.** H 4·5 G 2·39 — 2·50. Case 29. *Frac.* uneven, imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* white, colourless, gray, yellow, brown, red. *Str.* white. Brittle. B. fusible. In powder decomposed by hydrochloric acid.

Found in metallic veins, and in cavities of amygdaloidal rocks and basalt. Scotland, the Hartz Norway, Silesia, Oberstein. Derives its name from *αρμος a joint*, and *τεμνω to cut*, from the appearance of its twin crystals.

Phillipsite.—*Gismondine, Zeagonite, Lime Harmotome, Christianite, Abrazite, Staurotypous Kouphone Spar.*—(RO + SiO^2) + (AlO^3 + $3SiO^2$) + 5HO. **prismatic.** H 4·5 G 2·14 – 2·213. Case 29. *Frac.* conchoidal, uneven. Translucent, translucent on the edges. *Lus.* vitreous. *Col.* white, gray, colourless, blue, yellow, red. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in cavities of amygdaloid and basalt. Bohemia, Silesia, Bonn, Oberstein, Vesuvius, Sicily, Rome, Giant's Causeway. Resembles *Harmotome*, but distinguished from it by its lower specific gravity.

Felspar.—*Orthoclase, Orthotomous Felspar, Adularia, Murchisonite, Sanidine, Mikroklin, Amazon stone, Perthite.*—(KO + $3SiO^2$) + (AlO^3 + $3SiO^2$). **oblique.** H 6·0 G 2·53 — 2·59. Case 29. *Frac.* conchoidal, uneven. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* colourless, white, gray, green, brown, red, flesh-red, verdigris-green. *Str.* grayish-white. Brittle. B. fusible with difficulty. Not acted on by acids.

Adularia, or transparent Felspar, is found in plutonic and metamorphic rocks. St. Gotthardt, Mont Blanc, Dauphiné, Norway, Arran, Cornwall, Snowdon, Ceylon, Greenland.

Moon Stone, a transparent colourless felspar, from Ceylon, which presents a play of light; used as an ornamental stone.

Common Felspar. Italy, Silesia, Ireland, the Ural, Bohemia, Brazils.

Green Felspar (Amazon Stone), found on the east side of Lake Ilmen.

Glassy Felspar (Sanidine), found in trachyte, basaltic, conglomerate, and volcanic masses. The Rhine, Mexico, Chili, Baden, Hungary, Italy, Iceland, Cassel, Vesuvius, Arran.

Murchisonite is a flesh-red variety of felspar, found in rolled pebbles. Heavitree, Exeter.

Crystals of flesh-red felspar have been found in a copper furnace, and of adularia in an iron furnace.

The porcelain earth, or *Kaolin* of the Chinese, is produced by the decomposition of felspar. Felspar is extensively used in the manufacture of porcelain.

Pollux.—A hydrosilicate of alumina and potash. H 6·0 — 6·5 G 2·868 — 2·892. Case 29. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* white, colourless. B. fusible on the edges. Decomposed by acids.

Found with petalite in cavities of granite at Elba.

Labradorite.—*Labrador Felspar, Anhydrous Scolecite, Manilite, Silicite, Opaline Felspar, Polychromatic Felspar.*—(R O + Si O^2) + (Al O^3 + 2 Si O^2) where R is Ca or Na. **anorthic.** H 6·0 G 2·67 – 2·76. Case 30. *Frac.* imperfect conchoidal. Faintly translucent. *Lus.* vitreous. *Col.* gray, red, green, white, blue. B. fusible. Decomposed by concentrated hydrochloric acid when in powder.

Occurs principally as a constituent of rocks. The varieties which exhibit a play of colours are mostly derived from a coarse-grained hypersthene rock. Labrador, Russia, Finland, Ireland, the Tyrol, the Hartz, Scotland, Corsica, Saxony, Hessia, Sweden, Faröe, Norway, Ætna, Vesuvius. The play of colours is supposed to be produced by microscopic crystals of quartz included in the labradorite. It receives a good polish, and is valued for ornamental purposes on account of its beautiful colours.

Pectolite.—*Stellite, Osmelite, Woolastonite.*—4 R O + 3 Si O^2 + H O where R is Ca and Na. H 4·0 — 5·0 G 2·745 — 2·756. Case 29. Translucent on the edges. *Lus.* pearly. *Col.* grayish-white. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in spherical masses, in amygdaloid and felspar. Verona, the Tyrol, Lake Superior, New Jersey, Scotland, Bavaria.

Faujasite.—(R O + Si O^2) + (Al^2 O^3 + 2 Si O^2) + 9 H O where R is Na and Ca. **pyramidal.** H 5·0 G 1·923. Case 29. *Frac.* uneven. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* white, brown, colourless. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in cavities of amygdaloidal rock. Sassbach.

Latrobite. — *Diploite.*—A hydrosilicate of alumina. **anorthic.** H 5·0 – 6·0 G 2·720 — 2·722. Case 29. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* pale red. B. fusible.

Found with felspar, mica and calcite. Labrador and Massachusetts.

Albite. — *Pericline, Cleavelandite, Heterotomous Felspar, Tetartine, Tetarto-prismatic Felspar.*—(NaO + 3SiO^2) + (AlO^3 + 3SiO^2). **anorthic.** H 6·0 — 6·5 G 2·54 — 2·64. Case 30. *Frac.* imperfect conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* colourless, white, red, yellow, green, gray. *Str.* white. Brittle. B. fusible. Not decomposed by acids.

Found in granite, gneiss, greenstone, and lava. Dauphiné, the Pyrenees, Italy, Saxony, Silesia, the Hartz, the Tyrol, Moravia, Baden, Greenland, Siberia, the Alps, Sweden, Scotland, Ireland, Cornwall, Egypt, the Brazils, Massachusetts. Derives its name from *albus*, white.

Christianite.—*Anorthite, Amphodelite, Indianite, Lepolite, Anorthotomous Felspar.*—$(CaO + SiO^2) + (AlO^3 + SiO^2)$. **anorthic.** H 6·0 G 2·656 — 2·763. Case 30. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in dolomite, in lava, and in meteoric stones. Vesuvius, Java, Iceland, Columbia. Distinguished from topaz by inferior hardness and specific gravity.

Oligoclase.—*Antitomous Felspar, Soda Spodumene, Unionite.*—$(2NaO + 3SiO^2) + 2)AlO^3 + 3SiO^2)$. **anorthic.** H 6·0 G 2·63 – 2·74. Case 30. *Frac.* conchoidal, uneven. Translucent. *Lus.* vitreous. *Col.* greenish white and gray, red. *Str.* white. B. fusible. Not acted on by acids.

Found in granite, syenite, gneiss, porphyry, and basalt. Norway, Finland, the Ural, United States, the Hartz, Iceland. The oligoclase from Norway, which presents a play of colours produced by thin plates of hematite, is called *avanturine felspar* and *sunstone.* Derives its name from ολιγος *little*, and κλαω *to cleave.*

Porzellanspath.—$(3AlO^3 + SiO^2) + 3(CaO + SiO^2) + (NaO + 3SiO^2)$. **prismatic.** H 5·5 G 2·65 — 2·68. *Frac.* uneven. Translucent on the edges. *Lus.* vitreous. *Col.* yellowish and grayish-white. Brittle. B. fusible. Decomposed by concentrated hydrochloric acid.

Found in felspar and granite. Obernzell, near Passau. Decomposed by exposure to the air.

Leucite.—*Amphigene, Dodecahedral Zeolite, Trapezoidal Amphigene Spar.*—$(KO + SiO^2) + (AlO^3 + 3SiO^2)$. **cubic.** H 5·5 — 6·0 G 2·45 – 2·50. Case 31. *Frac.* conchoidal, uneven. Semi-transparent, translucent. *Lus.* vitreous. *Col.* grayish, yellowish, and reddish-white. Brittle. B. infusible. In powder decomposed by hydrochloric acid.

Found in lava, trachyte, and dolerite. Italy and the Rhine. Millstones formed of lava in which leucite was imbedded, have been found at Pompeii. It derives its name from λευκος, *white*, It has been called the white garnet.

Spodumene.—*Triphane, Prismatic Triphane Spar.*—A silicate of alumina.—**Oblique.** H 6·5 — 7·0 G 3·07 — 3·20. Case 31. *Frac.* uneven, splintery. Translucent on the edges. *Lus.* vitreous. *Col.* greenish-white and gray. *Str.* white. B. fusible. Not acted on by acids.

Found in gneiss and granite. Utö, the Tyrol, Ireland, Scotland, Massachusetts. Named from σποδος *ashes*, because it becomes ashy before the blowpipe.

Petalite.—*Prismatic Petaline Spar, Castor.*—A silicate of alumina. H 6·0 — 6·5 G 2·38 — 2·43. Case 31. *Frac.* imperfect, conchoidal. Translucent. *Lus.* vitreous. *Col.* white, green, red. *Str.* white. Brittle. B. fusible. Not decomposed by acids.

Found in masses and in granite. Utö, Massachusetts, Ontario, Elba. It was in the analysis of this mineral that *lithia* was first discovered.

Davyne.—*Davytic Kouphone Spar, Cancrinite, Cavolinite.*—A silicate of alumina, soda, and lime. **Rhombohedral.** H 5·5 G 2·42 — 2·46. Case 31. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* colourless, white, rose-red. B. fusible. Soluble in hydrochloric acid, leaving a jelly of silica.

Found in lava and miascite. Vesuvius, Maine, the Ural. Named in honour of Sir Humphrey Davy.

Nepheline.—*Rhombohedral Felspar, Rhombohedral Elain Spar, Elæolite, Sommite.*—($4 R O + 3 Si O^2$) + 2 ($2 Al O^3 + 3 Si O^2$), where R is Na, K, and Ca. **Rhombohedral.** H 5·5 – 6·0 G 2·58 – 2·64. Case 31. *Frac.* conchoidal, uneven. Transparent, feebly translucent. *Lus.* vitreous. *Col.* colourless, greenish-gray, bluish-green, flesh-red. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in basalt, dolerite, and syenite. Vesuvius, Rome, Heidelberg, Hessia, Saxony, Norway, the Ural. Derives its name from νεφελη *a cloud*, from the nebulous appearance assumed when fragments are thrown into nitric acid.

Scapolite.—*Meionite, Dypyre, Wernerite, Terenite, Paranthine Elain Spar, Glaucolite, Ekebergite, Tetraklasit, Nuttallite. Stroganowite.*—($3 Ca O + 2 Si O^2$) + 2 ($Al O^3 + Si O^2$). **pyramidal.** H 5·0 — 5·5 G 2·61 — 2·78. Case 31. *Frac.* conchoidal. Translucent, opaque. *Lus.* vitreous. *Col.* colourless, white, gray, green, red. *Str.* white. Brittle. B. fusible. Decomposed when in powder by hydrochloric acid.

Found in limestone and in iron mines. Vesuvius, Norway, Sweden, Finland, Moravia, Greenland, France, and North America. The name *meionite* is applied to the transparent varieties.

Dipyre.—*Schmelzstein.*—4 ($RO + Si O^2$) + 3 ($Al^2 O^3 + Si O^2$). G 2·646. Scratches glass. Case 31. Transparent, translucent. *Col.* whitish or reddish. B. fusible.

Found in hexagonal prisms with talc or chlorite in the Pyrenees.

Rhyacolite.—*Empyrodoxous Felspar.*—($RO + Si O^2$) + ($Al O^3 + 2 Si O^2$), where R is Na. K, and Ca. **oblique.** H 6·0 G 2·57 – 2·62. *Frac.* conchoidal, transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, grayish, yellowish, *Str.* white. Very brittle. B. fusible. Decomposed by hydrochloric acid.

Found in lava and volcanic matter. Vesuvius, Eiffel, Laach. Derives its name from ρυαξ, a *lava stream.*

Latrobite.—*Diploite.*—A silicate of alumina. **anorthic.** H 5·0 – 6·0 G 2·720 – 2·722. Case 31. *Frac.* uneven, translucent. *Lus.* vitreous. *Col.* pale red.

Found with felspar, mica, and calcite. Amitok, near Labrador.

Ittnerite.—*Dodecahedral Amphigene Spar, Haüyn.*—A hydrosilicate of alumina, soda, and lime. **cubic.** H 5·5 G 2·373 — 2·377. Case 31. *Frac.* flat conchoidal, translucent on the edges. *Lus.* resinous. *Col.* dark bluish-gray, smoke-gray, ash-gray. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in basalt. The Eichberg Baden.

Sarcolite. — *Octahedral Kouphone Spar.* — A silicate of lime and alumina. **pyramidal.** H 6·0 G 2·545. *Frac.* conchoidal, semi-transparent, translucent. *Lus.* vitreous. *Col.* flesh-red, white. Very brittle. B. fusible.

A rare mineral, found at Vesuvius.

Mica.—*Oblique Mica, Biaxial Mica, Potash Mica, Hemiprismatic Talk Glimmer, Muscovite.*—A silicate of alumina. **oblique.** H 2·5 G 2·8 — 3·1. Case 32. *Frac.* conchoidal. Transparent. *Col.* colourless, white, various shades of gray, brown, green, black. *Str.* white, gray. Sectile. B. fusible. Not decomposed by acids.

An essential constituent of granite, gneiss, and mica slate; found also in veins and cavities in porphyry, basalt, dolomite, limestone and lava. Vesuvius, Siberia, Finland, Greenland, United States, Norway. Occasionally found in the slags of furnaces. In Siberia thin sheets of mica are used for glazing windows, whence it has been called *Muscovy glass*. It is divisible into plates the $\frac{1}{250000}$th part of an inch in thickness.

Biotite.—*Hexagonal Mica, Uniaxial Mica, Magnesia Mica, Rubellan, Rhombohedral Talk Glimmer, Meroxen.*—$(3\,R\,O + 2\,Si\,O^2) + (Al\,O^3 + Si\,O^2)$ where R is Mg, K, and Fe. **rhombohedral.** H 2·0 — 2·5 G 2·78 — 2·95. Case 32. Transparent, translucent. *Lus.* metallic. *Col.* dark green, brown, verging into black. *Str.* white, pale greenish gray. Sectile. Thin leaves. Elastic. B. fusible with difficulty. Decomposed by sulphuric acid.

Found in granite and chlorite slate. The Ural, New Jersey, Greenland, Vesuvius, Siberia.

Lepidolite.—*Lithia Mica, Lithonite, Hemiprismatic Talk Glimmer.*—A silicate of alumina. **oblique.** H 2·0 — 3·0. G 2·8 — 3·0. Case 32. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* pearly, inclining to adamantine, vitreous. *Col.* white, green, gray, red, violet. *Str.* white. In thin leaves, elastic. B. fusible. Acted on by acids.

Occurs principally in granite. Moravia, Saxony, the Ural, Maine, Connecticut, Bohemia, Saxony and Cornwall.

Wichtisite.—A silicate of alumina and iron. G 3·03. *Frac.* imperfect, conchoidal. *Lus.* dull. *Col.* black. Magnetic.

Found at Wichtis, in Finland.

Glaucophane.—A silicate of alumina and iron. H 5·5 G 3·103 — 3·113. *Frac.* conchoidal. Translucent, nearly opaque. *Lus.* vitreous. *Col.* bluish-gray. *Str.* the same. Magnetic in powder. B. fusible. Imperfectly decomposed by acids.

Found in mica slate in the Island of Syra. Derives its name from γλαυκος *bluish-gray*, and φαινω *to appear*.

Margarite.—*Hemiprismatic Perl Glimmer, Emerylite, Corundellite, Clingmanite.*—A silicate of alumina. **oblique.** H 3·5 — 4·5 G 3·0 — 3·1. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* pearly, vitreous. *Col.* reddish- and greenish-white, pearl gray. *Str.* white. Rather brittle. B. fusible. Acted on by acids.

Found in the Tyrol with chlorite. United States, Asia Minor, the Ural.

Lepidomelane.—$(R^2\,O^3 + Si\,O^2) + (R^1 + Si\,O^2)$. H 3·0 G 3·0. Opaque. *Lus.* vitreous. *Col.* black. *Str.* green. Rather brittle. B. fusible. Easily decomposed by hydrochloric acid.

Found at Persberg, in Sweden. Derives its name from its colour and structure, λεπις *a scale*, and μελας *black*.

Talc.—*Prismatic Talk Glimmer, Potstone, Soapstone, Steatite.*—$6\,Mg\,O + 5\,Si\,O^2 + 2\,HO$. **prismatic?** H 1·0 — 1·5 G 2·6 — 2·8. Case 32. *Frac.* splintery. *Lus.* pearly, more or less translucent. *Col.* blue, green-gray by transmitted, and silver-white by reflected, light. *Str.* white. Thin leaves flexible but not elastic, unctuous to the touch. B. fusible with great difficulty. Not acted on by acids.

Occurs alone as talk-slate, and is a constituent of some granular rocks. The Tyrol, St. Gotthard, Sweden, Bavaria, Siberia, Scotland, Saxony, Bohemia, United States, Greenland. *Pot-stone*, or *lapis ollaris*, is a coarse and indistinctly granular variety, which, from its softness and tenacity, may be readily turned. It is used for the manufacture of cooking utensils and other vessels, for fire stones in furnaces, in powder for diminishing friction in machinery, and for removing oil stains from cloth.

Chlorite.—*Talk Chlorite, Ripidolith, Prismatic Talk Glimmer.*—A hydrosilicate of alumina and magnesia. **rhombohedral.** H 1·0 – 1·5 G 2·78 – 2·96. Case 32. Transparent, translucent. *Lus.* pearly. *Col.* green, blue, red. *Str.* green. In thin leaves, flexible; not elastic. B. fusible on the edges. Decomposed by strong sulphuric acid.

Found in granite, gneiss, diabase, and slaty rocks. The Ural, Norway, Sweden, Switzerland, the Tyrol, Saxony, Cornwall, Arran, Bute. Derives its name from χλωρος, *green.*

Ripidolite.—*Chlorite, Prismatic Talk Glimmer, Kämmererite, Leuchtenbergite, Pennine, Rodochrome.*—A hydrosilicate of alumina and magnesia. **Rhombohedral.** H 2·0 — 3·0 G 2·615 — 2·774. Case 32. Semi-transparent, translucent. *Lus.* vitreous. *Col.* green, violet. *Str.* white. In thin leaves, flexible, but not elastic. B. fusible on the edges. Decomposed by hot sulphuric acid.

Found in beds and veins in crystalline rocks. The Tyrol, Piedmont, the Ural, Silesia, the Pyrenees, Norway, Siberia, Styria, Baltimore. The violet varieties are called kämmererite. Its name is derived from ριπις *a fan.*

Loganite.—A hydrosilicate of alumina and magnesia. **Prismatic.** H 3·0 G 2·60 — 2·64. *Frac.* uneven. Subtranslucent. *Lus.* vitreous. *Col.* brown. *Str.* grayish-white. B. infusible. Partly decomposed by acids.

Found in limestone at Ottawa in Canada.

Pyrophillite.—2 $(Al^2 O^3 + 3 Si O^2) + 3 H O$ **prismatic.** H 1·0 G 2·785. Case 32. Translucent. *Lus.* pearly. *Col.* green, white. *Str.* white. B. fusible with difficulty. Partially decomposed by sulphuric acid.

Found in granite. The Ural, Belgium, the Brazils, United States.

Amphibole.—*Hornblende, Hemiprismatic Augite Spar, Smaragdite, Tremolite, Actinolite, Asbestos, Strahlstein, Raphilite, Cummingtonite.*—3 $(R O + S O^2) + (2 R O + S O^2)$, where R is Mg, Ca, and Fe. **oblique.** H 5·0 – 6·0 G 2·90 – 3·40. Cases 33 and 34. *Frac.* imperfect, conchoidal. Slightly translucent, opaque. *Lus.* vitreous. *Col.* colourless, white, green, brown, yellow, gray, black. *Str.* grayish-white, brown. Brittle. B. fusible. Slightly soluble in hydrochloric acid.

Grammatite.—The white, green, gray, semi-transparent, and translucent varieties, found in granular limestone, granite, and marble. St. Gotthardt, Transylvania, Bohemia, the Tyrol, Sweden, France, the Banat, Massachusetts, Aberdeenshire, Iona.

Actinote.—The greenish varieties, found in beds of iron ore. Saxony, Bohemia, Norway, Sweden, the Tyrol, Styria, Moravia.

Anthophyllite.—Found in Norway, Greenland, and United States.

Mountain Wood, Mountain Cork, &c., are fibrous varieties. Found in the Tyrol, Saxony, Bohemia, Sweden, Switzerland, Spain, the United States, Scotland.

Asbestos, or *Amianthus.*—A variety in flexible slender fibres. Corsica, Piedmont, Savoy, Saltzburg, the Tyrol, Dauphiné, Hungary, Silesia, United States, Cornwall, Aberdeenshire. (ασβεστος, *unconsumable*). The ancients wove this substance into cloth, which could be purified by burning.

Common Hornblende.—In dark green or black crystals, found in beds of iron ore. Norway, Sweden, Finland, Saxony, Bohemia, the Tyrol, Carinthia.

Basaltic Hornblende.—Black opaque crystals, embedded in basaltic rocks. Bohemia and Spain.

Pargasite.—*Hornblende.*—**Oblique.** H 5·0 – 6·0 G 3·07 – 3·08. Case 33. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* bluish-green. *Str.* white. B. fusible.

Found in limestone at Pargas in Finland.

Masonite.—*Chlorite Spar, Chloritoid, Barytophyllite.*—A hydrosilicate of alumina and iron. H 5·5 — 6·0 G 3·45 – 3·55. Case 33. Translucent in thin leaves. *Lus.* pearly. *Col.* blackish-green. *Str.* greenish-white. Brittle. B. fusible on the edges. Not acted on by acids.

Found in chlorite slate. Siberia, Rhode Island, the Tyrol, the Ural.

Arfvedsonite.—*Peritomous Augite Spar, Ægirine.*—**Oblique.** H 6·0 G 3·328 — 3·44. Case 33. *Frac.* imperfect, conchoidal. Opaque. *Lus.* vitreous. *Col.* black. *Str.* green. B. fusible.

Found in slate rock and beds of iron ore. Greenland, Norway, Arendal.

Krokydolite.—*Blue Asbestos.*—A hydrosilicate of iron. H 4·0 — 4·5 G 3·2 — 3·3. Case 34. Delicate fibres like asbestos. Translucent. *Lus.* silky. *Col.* indigo-blue. Tough, elastic, flexible. B. fusible. Not acted on by acids.

Found in syenite and quartz. South Africa, Norway, Greenland, Saltzburg. Derives its name from *κροκυs a flock of wool*, on account of the slender threads into which it is divisable.

Augite.—*Pyroxene, Diopside, Amianth, Malacolith, Paratomous, Augite Spar, Alalite, Baikalite, Jeffersonite, Goccolite, Sahlite, Omphazite, Pyrgome, Fassite.*—($Ca\,O + Si\,O^2$) + ($R\,O + Si\,O^2$), where R consists essentially of Mg and Fe. **oblique.** H 5·0 – 6·0 G 3·2 – 3·4. Case 34. *Frac.* conchoidal, uneven. Transparent, opaque. *Lus.* vitreous. *Col.* colourless, white, green, gray, black. *Str.* white, gray. Brittle. B. fusible. Slightly affected by acids.

Found in basalt, lava, limestone, meteoric stones, and slag of iron furnaces. Bohemia, France, Vesuvius, Teneriffe, Scotland, Finland, North America, Switzerland, Sweden, Norway. Can be formed artificially by fusing silica, lime, and magnesia in the right proportions. Some of the transparent varieties, when cut and polished, form handsome ornamental stones, of colours varying from the emerald to the yellow topaz.

Hypersthene.—*Paulite, Prismatoidal Schiller Spar, Labrador Hornblende, Diallage Metalloide.*—$RO + Si\,O^2$, where R is Mg and Fe. **oblique.** H 6·0 G 3·39. Case 34. *Frac.* uneven, opaque, translucent on the edges. *Lus.* pearly-vitreous. *Col.* grayish or greenish black. *Str.* greenish gray. B. fusible. Insoluble in acids.

Found imbedded in a greenstone rock, also associated with Labrador felspar. Labrador, Greenland, Norway, Skye, Saxony, Bohemia, the Tyrol, Sweden, Silesia, Berlin. Distinguished from bronzite by its cleavage. Cut and polished it presents a beautiful red colour and pearly lustre.

Diallage.—*Prismatic Schiller Spar, Diatomous Schiller Spar.*—**Oblique.** H 4·0 G 3·2 — 3·3. Case 34. *Frac.* uneven. Opaque. *Lus.* pearly or silky. *Col.* gray, greenish, brown. *Str.* white. B. fusible. Insoluble in acids.

Found with amphibole. The Hartz, Silesia, Apennines, the Ural.

Ilvaite.—*Lievrite, Yenite, Fer Calcaréo Siliceux, Diprismatic Iron Ore.*—($Fe^2\,O^3 + Si\,O^2$) + 2 ($R^2\,O + Si\,O^2$), where R is Ca and Fe. **prismatic.** H 5·5 – 6·0 G 3·989 – 4·015. Case 34. *Frac.* imperfect conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* black, inclining to gray, brown, and green. *Str.* black. Brittle. B. fusible. Decomposed by warm hydrochloric acid, leaving a jelly of silica.

Found imbedded in augite in Elba, Norway, Silesia, Moravia, Siberia, Greenland.

Acmite.—*Paratomous Augite Spar.*—($2\,Fe^2\,O^3 + 3\,Si\,O^2$) + 2 ($Na\,O + Si\,O^2$). **oblique.** H 6·0 – 6·5 G 3·53 – 3·55. Case 34. *Frac.* imperfect conchoidal.

Nearly opaque. *Lus.* vitreous. *Col.* brownish-black or reddish-brown. *Str.* greenish-gray. B. fusible. Partially decomposed by hydrochloric and sulphuric acids.

Found in granite and syenite. Norway. A scarce mineral. Derives its name from *ακμη*, *a point*, on account of the form of its crystals, some of which have been found a foot in length.

Epidote.—*Prismatoidal Augite Spar, Pistacite, Thallite, Withamite, Akanticon, Scorza, Delphinite, Arendalite, Thulite, Puschkinite, Achmatite.*—$(3\ CaO + 2\ SiO^2) + 2\ (R^2O^3 + Si\ O^2)$, where R^2 is Al, Fe^2, or Mn^2. **oblique.** H 6·5 G 3·0 – 3·5. Case 35. *Frac.* uneven, semi-transparent. *Lus.* vitreous. *Col.* green, yellow, brown, red, black. *Str.* gray. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Occurs in granite, syenite, trap, porphyry, and slate rocks. Norway, Sweden, the Alps, Dauphiné, the Ural, Pyrenees, Bohemia, Finland, Greenland, Norway.

Zoisite.—Oblique. Case 35. *Lus.* vitreous. *Col.* grayish-white, yellowish-gray, brown, green. B. fusible.

Found in Carinthia, the Tyrol, Saltzburg, Bayreuth, Bavaria, the Ural.

Somervillite.—*Melilite, Humboldtilite, Zurlite.*—$2\ (3\ RO + 2\ Si\ O^2) + (R'\ O^3 + Si\ O^2)$, where R is Ca, Mg, Na, and K, and R′ is Al and Fe^2. **pyramidal.** H 5·0 — 5·5 G 2·90 – 3·104. Case 35. *Frac.* conchoidal, uneven, semi-transparent. Opaque. *Lus.* vitreous. *Col.* white, green, yellow, brown. *Str.* white. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found with calcite and in lava. Monte Somma and Capo di Bove.

Bastite.—*Schiller Spar, Metalloid Diallage.*—$4\ (RO + Si\ O^2) + (Mgo + 4HO)$ where R is Mg, Ca and Fe. H 3·5 — 4·0 G 2·6 2·8. Case 35. *Frac.* uneven. Translucent. *Lus.* pearly. *Col.* green, brown, yellow. *Str.* greenish-white. B. fusible on the edges. Decomposed by sulphuric acid.

Found in the euphotide of the Hartz.

Babingtonite.—*Axotomous Augite Spar.*—**anorthic.** H 5·5 — 6·0. G 3·355 – 3·406. Case 35. *Frac.* imperfect, conchoidal. *Lus.* vitreous. *Col.* black. *Str.* greenish-gray. Brittle. B. fusible. Decomposed by boiling hydrochloric acid.

Found in magnetite, quartz, felspar, and prehnite. Norway, Shetland, New York, Massachusetts.

Idocrase.—*Pyramidal Garnet, Vesuvian, Egeran, Loboit, Frugardit, Cyprine.*—$(3CaO + 2SiO^2) + (AlO^3 + SiO^2)$. **pyramidal.** H 6·5 G 3·35 – 3·45. Case 35. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* green, yellow, brown, black. *Str.* white. B. fusible. Imperfectly decomposed by hydrochloric acid.

Found in dolomite, serpentine, and limestone. The Ural, St. Gotthardt, Norway, Bohemia, Sweden, Finland, the Pyrenees, Saxony, Ireland, Spain, North America. At Naples and Turin ornaments are formed of idocrase, which takes a good polish, and are sold under the denomination of hyacinth, crysolite, &c.

Uwarowite.—*Chrome and Lime Garnet.*—$(3CaO + 2SiO^2) + (Cr^2O^3 + SiO^2)$. **cubic.** H 7·5 – 8·0 G 3·418. Case 36. *Frac.* imperfect, conchoidal. Translucent. *Lus.* vitreous. *Col.* emerald-green. *Str.* greenish-white. B. infusible.

Found in the Ural,

Garnet.—*Allochroit, Dodecahedral Garnet.*—$(3RO + 2SiO^2) + (R^1O^3 + SiO^2)$, where R is Ca, Mg, Fe; and R^1 is Al, Fe^2. **cubic.** H 6·5 – 7·5 G 3·1 – 4·3. Case 36. *Frac.* conchoidal. Transparent, opaque. *Lus.* vitreous. *Col.* red, brown, yellow, white, green, black. *Str.* white, gray. B. fusible. Soluble imperfectly in hydrochloric acid.

Almandine, the transparent red garnet, found in sand, alluvial soil, and gneiss. Pegu, Ceylon, Hindostan, Brazils.

Common Garnet, found in Saxony, Norway, Sweden, Finland, Hungary, Stiria, the Tyrol, Moravia, Silesia, Siberia.

Calophonite, granular brown garnet. Arendal and North America.

Grossular Garnet and *Pyrenaite*, a light-green variety. Kamtschatka.

Melanite, black garnet. Vesuvius, Rome, Norway, the Pyrenees.

Topazolite, honey-yellow garnet. Piedmont.

Essonite or *Cinnamon Stone*, *Romanozovite*, reddish-yellow garnet. Ceylon, Egypt, Finland, Piedmont.

Pyrope, dark-red variety of garnet. Saxony, Bohemia, Ceylon.

When the garnet is of a rich colour and free from flaws, it forms a valuable gem; it may be distinguished from corundum or spinel by its colour being duller. Coarse garnets reduced to a fine powder, are used instead of emery for polishing metals.

Gehlenite.—*Stylobite, Pyramidal Adiaphane Spar.*—$(3\ CaO + SiO^2) + (AlO^3 + SiO^2)$. **pyramidal.** H 5·5 – 6·0 G 2·99 – 3·10. Case 36. *Frac.* imperfect conchoidal. Translucent on the edges. *Lus.* resinous. *Col.* gray, brown, green. *Str.* white. B. fusible with great difficulty. Decomposed by warm hydrochloric acid, leaving a jelly of silica.

Found imbedded in calcite, near Vigo; also in the slags of iron furnaces.

Cordierite.—*Iolite, Pelioma, Prismatic Quartz, Dichroite, Steinheilite.*—$(Al\ O^3 + 3\ Si\ O^2) + 2\ (Mg\ O + Si\ O^2)$. **prismatic.** H 7·0 – 7·5 G 2·600 — 2·718. Case 36. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* blue, inclining to gray or black. *Str.* white. B. fusible on the edges. Imperfectly decomposed by acids.

Found in gneiss. Spain, Bavaria, Finland, Norway, Sweden, Greenland, Siberia, North America, Ceylon. *Pinite, Gieseckite, Oosite, Killinite, Fahlunite, Triclassite, Bonsdorffite, Esmarkite, Aspasiolite, Pyrargyllite, Chlorophyllite, Gigantolite, Praseolite, Iberite, Weissite*, are supposed to be *Cordierite*, more or less changed by decomposition. A transparent variety from Ceylon, of an intense blue colour, is called *Sapphire d'eau*; it is inferior in hardness and lustre to the sapphire, and its specific gravity is less.

Sordawalite.—Massive. H 4·0 — 4·5 G 2·55 — 2·62. Case 36. *Frac.* conchoidal. Opaque. *Lus.* resinous. *Col.* black, brown, green. *Str.* brown. Brittle. B. fusible. Imperfectly decomposed by acids.

Found at Sordawla in Finland.

Bragationite.—Oblique. H 6·3 G 4·115. *Frac.* uneven. Opaque. *Lus.* vitreous. *Col.* black. *Str.* dark brown. B. fusible.

Found at Slatoust in the Ural.

Bucklandite.—*Dystomic Augite Spar.*—$(3\ Fe\ O + 2\ Si\ O^2) + 2\ (Fe^2\ O^3 + Si\ O^2)$. **oblique.** H 6·0 G 3·865. Case 36. *Frac.* uneven. Opaque. *Lus.* vitreous. *Col.* dark brown, black. *Str.* gray. B. fusible.

Found in volcanic rocks and granite. Arendal, Laach, Siberia. [A very rare mineral, having a general resemblance to augite.

Staurolite.—*Grenatite, Prismatic Garnet, Prismatoidal Garnet.*—$R^2 O^3 + Si O^2$ where R is Al and 2 Fe. **prismatic.** H 7·0 — 7·5 G 3·52 — 3·79. Case 31. *Frac.* conchoidal, uneven. Translucent. *Lus.* vitreous, inclining to resinous. *Col.* reddish-brown, blackish-brown. *Str.* white. B. nearly infusible. Partially decomposed by sulphuric acid.

Found in mica, talc, or clay slate, rarely in gneiss. St. Gotthardt, Transylvania, Moravia, Spain, Var, Hebrides, Aberdeenshire, the Ural, New England. The crystals of this mineral are sometimes curiously associated with those of Kyanite, the crystals of the two substances being disposed sometimes parallel, as if forming one crystal, and sometimes at right angles to the axis. Named from *σταυρος a cross.*

Karpholite.—A hydrosilicate of manganese. H 5·0 — 5·5 G 2·935. Case 36. Feebly translucent. Opaque. *Lus.* vitreous. *Col.* yellow. *Str.* white. B. fusible. Scarcely acted on by hydrochloric acid.

Found in acicular and capillary crystals in granite. Bohemia. Named from *καρφος, a straw*, on account of its colour.

Emerald.—*Beryl, Aquamarine, Davidsonite, Goshenite, Dirhombohedric Smaragd.*—$(Al O^2 + 3 Si O^2) + 3 (G O + Si O^2)$. **rhombohedral.** H 7·5 – 8·0 G 2·67 – 2·75. Case 37. *Frac.* conchoidal, uneven. Transparent, translucent. *Lus.* vitreous. *Col.* green in the emerald, colourless blue, yellow and red for the beryl. *Str.* white. B. fusible on the edges.

The *Emerald* is found in Peru, Egypt, Siberia, and Norway.

The *Beryl*, or *aquamarine*, in Saxony, Bohemia, Bavaria, Elba, France, Norway, Sweden, Finland, Siberia, North America, Brazils, Ireland, and Aberdeenshire. The emerald is most valuable as a gem.

Euclase.—*Prismatic Smaragd.*—$(Al O^3 + 3 Si O^2) + 6 (2 G O + Si O^2)$. **Oblique.** H 7·5 G 3·0 — 3·1. Case 37. *Frac.* conchoidal. Transparent, semi-transparent. *Lus.* vitreous. *Col.* green, yellow, blue, very pale. *Str.* white. B. fusible. Not acted on by acids.

A rare mineral; found in chlorite slate, mica and fluor. Brazils, Connecticut, Peru. Derives its name from *εὖ easily*, and *κλαω to break*, on account of its brittleness.

Phenakite. — *Rhombohedral Smaragd.* — $2 G O + Si O^2$. **rhombohedral.** H 7·5 – 8·0 G 2·96 — 3·0. Case 37. *Frac.* conchoidal, uneven. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, yellow, brown. B. Infusible. Insoluble in acids.

Found with iron ore, emerald, green felspar, and topaz. Alsace and Siberia. Derives its name from *φεναξ a deceiver*, on account of its having been mistaken for quartz.

Helvin.—*Tetrahedral Garnet.*—$3 (2 RO + Si O^2) + Mn S$ where R is Fe, Mn, and G. **cubic.** H 6·0 — 6·5 G 3·1 — 3·3. Case 37. *Frac.* uneven. Translucent on the edges. *Lus.* vitreous. *Col.* brown, yellow, green. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid leaving a jelly of silica.

A very rare mineral; found in gneiss. Saxony, Norway, and Bavaria. Named from *ἥλιος the sun*, on account of its yellow colour.

Gadolonite.—*Hemiprismatic Melane ore, Ytterbite.* **prismatic.** H 6·5 G 4·2 – 4·4. Case 37. *Frac.* conchoidal, uneven. Opaque. *Lus.* vitreous. *Col.* black, seldom red. *Str.* greenish-gray. B. infusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in granite, gneiss, syenite and trap. Stockholm, Fahlun, Ceylon, Galway in *Ireland.* Yttria was first discovered by Gadolin in this ore.

Allanite.—*Orthite, Cerine, Bagrationite, Uralorthite, Xanthortite, Pyrorthite, Black Siliceous Oxide of Cerium, Tetarto Prismatic Melane Ore.*—(3 R O + 2 Si O^2) + (R^1 O^3 + Si O^2) where R is Ca, Ce, and Fe, and R′ is Fe^2 or Al. **oblique.** H 6·0 G 3·1 —4·2. Case 38. *Frac.* conchoidal. Opaque. *Lus.* imperfect, metallic. *Col.* black, brown, green. *Str.* greenish or brownish-gray. Brittle. B. fusible.

Found in granite. Greenland, Norway, Sweden, the Ural.

Tscheffkinite.—H 5·3 G 4·508 — 4·549. Case 37. *Frac.* conchoidal. Almost opaque. *Lus.* vitreous. *Col.* black. *Str.* brown. B. fusible. Soluble in hydrochloric acid, leaving a jelly of silica.

Found with felspar in the Ilmen mountains near Miask.

Rutile.—*Oxide of Titanium, Peritomous Titanium Ore, Titanschorl, Nigrine, Gallicinite, Sagenite, Crispite.*—Ti O^2. **pyramidal.** H 6·0 — 6·5 G 4·22 — 4·30. Case 37. *Frac.* conchoidal, uneven. Translucent, opaque. *Lus.* adamantine. *Col.* reddish-brown, red, yellow, black. *Str.* very light brown. B. infusible. Soluble with difficulty, when powdered, in hot concentrated sulphuric acid.

In veins and beds with quartz, felspar, and in alluvium. Hungary, Styria, Norway, the Tyrol, Bohemia, Switzerland, Ceylon, France, Siberia, North and South America, Fife, Perthshire, Shetland. Used in painting porcelain.

Anatase.—*Pyramidal Titanium Ore, Octahedrite, Oisanite.*—Ti O^2. **pyramidal.** H 5·5 — 6·0 G 3·83 — 3·93. Case 37. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* adamantine. *Col.* blue, black, red, yellow, brown. *Str.* white. Brittle. B. infusible. Not decomposed by acids.

Found in granite and mica slate. Dauphiné, Switzerland, Cornwall, Spain, the Ural, Norway, Brazils. The crystals from the Brazils resemble the diamond so much in colour and general appearance, as often to deceive lapidaries and mineral dealers.

Pyrochlore.—*Microlite, Octahedral Titanium Ore.*—**Cubic.** H 5·3 — 5·5 G 4·19 — 4·33. Case 37. *Frac.* conchoidal. Opaque, translucent on the edges. *Lus.* resinous. *Col.* dark brown. *Str.* light brown. Rather brittle. B. fusible. Decomposed in powder by concentrated sulphuric acid.

Found in syenite and granite. Norway, the Ural.

Sphene.—*Titanite, Brown and Yellow Menachine Ore, Calcareo-siliceous Titanium, Greenovite, Lederite, Pictite, Arpidelite, Prismatic Titanium Ore.*—(2 Ca O + Si O^2) + (2 Ti O + Si O^2). **oblique.** H 5·0 — 5·5 G 3·3 — 3·7. Case 37. *Frac.* imperfect, conchoidal. Transparent. *Lus.* adamantine. *Col.* yellow, green, brown, red. B. fusible on the edges. Decomposed by sulphuric acid.

Found in granite, syenite, gneiss, slate, marble, basalt, and lava. Piedmont, the Tyrol, the Pyrenees, the Ural, Norway, Sweden, Bohemia, Moravia, France, Scotland, Ireland, Greenland, Brazils, United States, Greek Islands. Derives its name from σφην *a wedge*, on account of the shape of its crystals.

Brookite.—*Prismatic Titanium Ore, Juranite, Arkansite, Eumanite.*—Ti O^2. **prismatic.** H 6·0 G 4·125 — 4·170. Case 37. *Frac.* uneven. Translucent, opaque. *Lus.* metallic. *Col.* yellowish-brown, reddish-brown, hyacinth-red. *Str.* yellowish-white. Brittle. B. infusible. In powder soluble in hot concentrated sulphuric acid.

Dauphiné, Switzerland, the Ural, Caernarvonshire, Ætna, Arkansas. It is not a common mineral.

Perowskite.—($CaO + TiO^2$). **cubic.** H 5·8 G 3·99 — 4·017. Case 37. Opaque. *Lus.* adamantine. *Col.* black, reddish-brown. *Str.* grayish-white. B. infusible. Acted on very feebly by hydrochloric acid.

Found in limestone and chlorite slate. Vogsburg and the Ural.

Mengite.—Supposed to contain oxides of iron and manganese, titanic acid and zirconia. **prismatic.** H 5·0 — 5·5 G 5·43. *Frac.* uneven, conchoidal. Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* brown. B. infusible. Soluble in hot concentrated sulphuric acid.

Found in albite in Siberia.

Polymignite.—*Prismatic Melane Ore.*—**Prismatic.** H 6·5 G 4·75 — 4·81. Case 37. *Frac.* conchoidal. Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* dark brown. Brittle. B. infusible. Decomposed in powder by concentrated sulphuric acid.

Found in syenite and basalt in Norway.

Fergusonite.—*Pyramidal Melane Ore.*—($6RO + TaO^3$), where R is Y, Ce, and Zr. **pyramidal.** H 5·5 — 6·0 G 5·8 — 5·9. Case 37. *Frac.* conchoidal. Opaque. *Lus.* imperfect, metallic. *Col.* blackish-brown. *Str.* pale brown. Brittle. B. infusible.

Found in quartz in Greenland.

Polykrase.—**Prismatic.** H 6·0 G 5·105. *Frac.* conchoidal. Translucent in thin fragments. *Lus.* metallic. *Col.* black. *Str.* grayish-brown. B. infusible. Decomposed by hot sulphuric acid.

Found in granite in Norway.

Æschynite.—**Prismatic.** H 5·5 G 5·1 — 5·2. Case 37. *Frac.* imperfect conchoidal. Faintly translucent on the edges. Opaque. *Lus.* imperfect metallic. *Col.* iron, black, brown. *Str.* yellowish-brown. Brittle. B. nearly infusible. Partially decomposed by concentrated sulphuric acid.

Found in a rock consisting of felspar, albite, and mica, near Miask, in the Ural.

Malacone.—**Pyramidal.** H 6·0 G 3·903 — 3·913. *Frac.* conchoidal. *Lus.* vitreous. B. infusible. Decomposed by hot sulphuric acid.

Found at Hitteröe in Norway.

Œrstedite.—**Pyramidal.** H 5·5 G 3·629. Case 37. Translucent. *Lus.* adamantine. *Col.* yellowish-brown. B. infusible.

Found at Arendal in Norway.

Mosandrite.—H 4·0 G 2·93. Case 37. Translucent in thin fragments. *Lus.* resinous. *Col.* brown. *Str.* grayish-brown. B. fusible. Decomposed by hydrochloric acid.

Found in syenite. Norway.

Keilhauite.—*Yttrotitanite.* H 6·5 G 3·69. Case 37. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* brownish-black. *Str.* grayish-brown. B. fusible. Decomposed by hydrochloric acid.

Found at Buön in Norway.

Iserine.—*Hexahedral Iron Ore, Oxidulous Titanitic Iron.*—$FeO + R^2O^3$, where

R is Fe or Ti. **cubic.** H 6·0 – 6·5 G 4·86 – 5·10. Case 37. *Frac.* conchoidal Opaque. *Lus.* metallic. *Col.* iron-black. *Str.* black. Brittle. Magnetic. B. infusible

Found in basalt and dolorite, also as sand in alluvium. Saxony, Upper Lusatia, Unkel, the Rhine, France, Calabria. Distinguished from nigrine, a variety of rutile, by its inferior hardness and black streak.

Ilmenite.—*Titanitic Iron, Axotomous Iron Ore, Crichtonite, Kibdelophane, Menaccanite.*—$Ti\ O^3$ with $Fe\ O^3$ in various proportions. **rhombohedral.** H 5·0 – 6·0 G 4·66 – 5·31. Case 37. *Frac.* conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* iron-black. *Str.* black, brown. Brittle. B. infusible.

Found imbedded in serpentine, and also disseminated through sand. Saltzburg, Siberia, France, Bohemia, St. Domingo.

Niobite.—*Tantalite, Baierine, Torrelite, Hemiprismatic Tantal Ore, Columbite.* **prismatic.** H 6·0 G 5·32 – 6·39. Case 38. *Frac.* imperfect conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* black. *Str.* dark-brown or black. B. infusible. Not acted on by acids.

Found in granite. Rabenstein, Ilmen, Connecticut, Massachusetts, and New Hampshire.

Tantalite.—*Prismatic Tantalum Ore, Columbite.*—$Fe\ O + Ta\ O^3$. **prismatic.** H 6·0 – 6·5 G 7·0 – 8·0. Case 38. *Frac.* conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* iron-black. *Str.* brown. B. fusible. Not acted on by acids.

Found in granite, felspar, and quartz. Sweden, Bavaria, Bohemia, Connecticut, Massachusetts.

Yttrotantalite.—$(3\ RO + Ta\ O^3)$, where R is Y, Ca, Fe, U. H 5·0 – 5·5 G 5·39 — 5·88. Case 38. *Frac.* conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* black, brown. *Str.* gray or white. B. infusible. Not acted on by acids.

Found in indistinctly formed crystals, in felspar and granite. Sweden, Fahlun, and the Ural.

Samarskite.—*Uranotantal, Yttro-ilmenite.* **prismatic.** H 5·5 G 5·617 – 5·715. Case 38. *Frac.* conchoidal. Opaque. *Lus.* imperfect metallic. *Col.* black. *Str.* dark-brown. B. fusible on the edges. Soluble in hydrochloric acid.

Found in felspar. Ilmen, near Miask.

Wohlerite.—H 5·5 G 3·41. Case 38. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* yellow, brown, gray. *Str.* yellowish-white. B. fusible. Decomposed by warm concentrated hydrochloric acid.

Found in tabular and columnar crystals in syenite. Norway.

Euxenite.—H 6·5 G 4·6. Case 38. *Frac.* imperfect conchoidal. Translucent. *Lus.* resinous. *Col.* brownish-black. *Str.* reddish-brown. B. infusible. Not acted on by acids.

A rare mineral, found in Norway, named from *ευξενος a stranger*, on account of its rarity.

Schorlomite.—*Ferrotitanite.*—$2(RO + SiO^2) + (2RO + TiO^2)$, where R is Fe, Ca, and Mg. **amorphous.** H 7·5 G 3·783 – 3·807. *Frac.* conchoidal. Opaque. *Lus.* vitreous. *Col.* black, iridescent. B. fusible on the edges. Decomposed partially by hydrochloric acid.

Found massive with brookite. Arkansas.

Antimonocher.—*Cervantite, Antimonial Ochre, Antimonial Oxide.*—$SbO^3 + SbO^5 + 2HO$. **amorphous.** Very soft. G 5·28. Case 38. *Frac.* uneven, earthy. Opaque. *Lus.* dull. *Col.* yellow. *Str.* yellowish-white, shining. Brittle. B. volatilizes.

Found with antimonite, in Spain, Hungary, Bavaria, Mexico, Padstow, Cornwall.

Kermes.—*Red Antimony, Antimony Blende, Prismatic Purple Blende.*—($SbO^3 + 2SbS^3$). **oblique.** H 1·5 G 4·5 – 4·6. Case 38. Faintly translucent. *Lus.* adamantine. *Col.* cherry-red. *Str.* red. Sectile. B. fusible. Soluble in hydrochloric acid.

Found in crystalline slate and transition rocks. Saxony, Bohemia, Hungary, Dauphiné.

Zundererz.—An impure arsenical sulphuret of antimony and lead. *Col.* dirty red.

Found in capillary crystals interlaced, and presenting the appearance of flakes of tinder. The Hartz.

Valentinite.—*Exitèle, Oxide of Antimony, White Antimony, Prismatic Antimony Baryte.*—SbO^3. **prismatic.** H 2·5 – 3·0 G 5·566. Case 38. Semi-transparent, translucent. *Lus.* adamantine. *Col.* white, gray, yellow, brown, red. *Str.* white. Sectile. B. fusible. Soluble in nitro-muriatic acid.

Found in Bohemia, Saxony, Hungary, Nassau, Dauphiné. Oxide of antimony, crystallized artificially, is dimorphous; the crystals belonging to the cubical or prismatic system, according as they are formed at a high or low temperature.

Scheelite.—*Tungstate of Lime, Tungsten, Pyramidal Scheel Baryta.*—$CaO + WO^3$. **pyramidal.** H 4·5 G 5·9 — 6·22. Case 38. *Frac.* imperfect conchoidal. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* white, gray, yellow, brown, orange, red, green. *Str.* white. Brittle. B. fusible. Decomposed when in powder by warm hydrochloric and nitric acids.

Found in gold, tin, and copper mines. Bohemia, Saxony, Cornwall, Cumberland, Connecticut, Hungary, France, the Hartz, Siberia, Chili.

Wolfram.—*Tungstate of Iron, Prismatic Scheel Ore.*—($RO + WO^3$), where R is Fe and Mn. **prismatic.** H 5·5 G 7·0 – 7·5. Case 38. *Frac.* uneven. Opaque. *Lus.* adamantine. *Col.* brownish-black. *Str.* brown, black. Slightly magnetic. B. fusible. Decomposed by hydrochloric acid.

Found in veins of quartz and granite. Bohemia, Saxony, France, the Hartz, Cornwall Cumberland, Hebrides, Ceylon, Siberia, Connecticut, South America.

Stolzite.—*Tungstate of Lead, Scheel Lead, Dystomous Lead Baryta.*—$PbO + WO^3$. **pyramidal.** H 3·0 G 7·9 — 8·09. Case 38. *Frac.* conchoidal. Semi-transparent. *Lus.* resinous. *Col.* gray, brown, yellow, green. *Str.* grayish-white. Brittle. B. fusible. Soluble in nitric acid.

Found with quartz and mica, in the tin mines of Zimmwald, in Bohemia. Carinthia, Chili.

Vanadinite.—*Vanadiate of Lead, Johnstonite.*—$PbCl + 2PbO + (3PbO + 3VO^3)$. **rhombohedral.** H 3·0 G 6·83 – 6·89. Case 38. *Frac.* conchoidal. Feebly translucent. Opaque. *Lus.* vitreous. *Col.* yellow, brown, green, white. *Str.* white, yellow. B. fusible. Soluble in nitric acid.

Found in Mexico, the Ural, and Dumfriesshire.

Dechenite.—($PbO + VO^3$). H 4·0 G 5·81. *Lus.* greasy. *Col.* dull-red. *Str* yellowish. B. fusible.

Found in Bavaria.

Volborthite.—*Vanadiate of Copper.*—$4CuO + VO^3 + HO$, part of the Cu replaced by Ca. **rhombohedral.** H 3·0 – 3·5 G 3·459 – 3·860. Case 38. Translucent. *Lus.* pearly. *Col.* green, gray. *Str.* yellowish-green.

Found in the permian formation. Ingowskoi, Thuringia.

Molybdanocher.—*Oxide of Molybdenum, Molybdic Acid.*—$Mo\ O^3$. Earthy. Case 39. Opaque. *Lus.* dull. *Col.* orange-yellow. B. fusible. Soluble in hydrochloric acid, in potash, and in ammonia.

Found with molybdanite. Norway, Scotland, and the Tyrol.

Wulfenite.—*Molybdate of Lead, Yellow Lead Ore, Carinthite, Pyramidal Lead Baryta.*—$PbO + MoO^3$. **pyramidal.** H 3·0 G 6·3 — 6·9. Case 39. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* resinous. *Col.* colourless, yellow, green, red, gray, brown. *Str.* white. Brittle. B. fusible. Decomposed by acids.

Found in crystals and massive, and in lead mines. Carinthia, Austria, Hungary, the Banat, the Tyrol, Saxony, Bavaria, Massachusetts, Pennsylvania, Mexico.

Wolchonskoite.—(A hydrosilicate of chrome ?) H 2·0 — 2·5 G 2·213 — 2·303. Case 39. *Frac.* conchoidal. Opaque. *Lus.* dull. *Col.* green. *Str.* lighter green. B. infusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in veins and nodules. Perm in Russia.

Chromochre.—Massive and investing other minerals. Case 39. Opaque. *Lus.* dull. *Col.* green.

Found in conglomerate and porphyry. France, Sweden, Silesia.

Lehmannite.—*Chromate of Lead, Red Lead Ore, Hemiprismatic Lead Baryta, Kalochrome, Crocoisite, Krokoite.*—$PbO + CrO^3$. **oblique.** H 2·5 — 3·0 G 5·9 — 6·1. Case 39. *Frac.* conchoidal, uneven. Translucent. *Lus.* adamantine. *Col.* red. *Str.* orange. Sectile. B. fusible. Decomposed by warm hydrochloric acid.

Found with quartz in granite and talcose slate. Siberia, the Ural, Brazils.

Phœnicite.—*Melanochroite, Phönikochroit, Phönicit.*—$3\ PbO + 2\ CrO^3$ H 3·0 — 3·5 G 5·75. Translucent on the edges. *Lus.* resinous. *Col.* red. *Str.* brick-red. Slightly brittle. B. fusible. Decomposed by hydrochloric acid.

Found in veins of quartz in the Ural.

Vanquelinite.—*Chromate of Lead and Copper, Hemiprismatic Olive Malachite.*—$(3\ CuO + 2\ CrO^3) + 2\ (3\ PbO + 2\ CrO^3)$. **oblique.** H 3·0 — 3·5 G 5·75. Case 39. *Frac.* flat, conchoidal. Slightly translucent. Opaque. *Lus.* waxy. *Col.* green, brown. *Str.* green. B. fusible. Soluble in nitric acid.

Found in veins of quartz. The Ural, Brazils, North America.

Chromite.—*Chromate of Iron, Octahedral Chrome Ore, Prismatic Chrome Ore.*—$RO + R'^2O^3$, where R is Fe, Mg, or Cr, and R' is Cr, Al, and perhaps Fe. **cubic.** H 5·5 G 4·40 — 4·59. Case 39. *Frac.* uneven, imperfect conchoidal. Opaque.

Lus. metallic. *Col.* iron-black, brownish-black. *Str.* dark-brown. Brittle. Sometimes slightly magnetic. B. infusible. Soluble in bisulphate of potash.

Found in serpentine, limestone, and in streams. France, Stiria, Banffshire, Stirlingshire, Silesia, Bohemia, Norway, Siberia, Maryland, Pennsylvania, Vermont, New Jersey, Massachusetts, Baltimore, St. Domingo. The large proportion of chrome renders this a highly valuable mineral. In combination with the oxides of other minerals it yields green, yellow, and red pigments, used in oil painting, dyeing and colouring porcelain.

Sassoline.—*Native Boracic Acid, Prismatic Boracic Acid.*—$BoO^3 + 3HO$. **amorthic**. H 1·0 G 1·48. Case 39. Transparent, translucent. *Lus.* pearly. *Col.* white, colourless, grayish-white, yellowish-white. *Str.* white, unctuous to the touch. *Taste*, acid and bitter. Soluble in water and in alcohol.

Found, mixed with sulphur, in the islands of Vulcano and Stromboli, and in the water of the hot springs of Sasso, in Tuscany. Used in the manufacture of borax.

Hayesine.—*Hydroborocalcite.*—$2(CaO + BO^3) + 6HO$. Case 39. *Col.* white.

Found abundantly, in fibrous masses, on the dry plains near Iquique, in Peru.

Hydroboracite.—$(3CaO + 4BO^3) + (3MgO + 4BO^3) + 18HO$. H 2·0 G 1·9. In thin leaves translucent. *Col.* white. B. fusible. Soluble in hot hydrochloric and nitric acids.

Found in fibrous masses in the Caucasus.

Tincal.—*Borate of Soda, Prismatic Borax Salt.*—$NaO + 2BO^3 + 10HO$. **oblique**. H 2·0 – 2·5 G 1·716. Case 39. *Frac.* conchoidal. Transparent, translucent. *Lus.* resinous. *Col.* colourless, white, gray, yellow, green. *Str.* white. Rather brittle. Taste, alkaline, sweetish. B. fusible. Soluble in water.

Found on the shores of some lakes. Thibet, Nepaul, China, Ceylon, South America. Tincal, when purified, forms the refined borax of commerce. It is used as a flux in glass manufactories and in soldering.

Boracite.—*Borate of Magnesia, Tetrahedral Boracite.*—$3MgO + 4BO^3$. **cubic**. H 7·0 G 2·83 – 2·98. Case 39. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* white, colourless, gray, yellow, green, brown. *Str.* white. Pyroelectric. B. fusible. Soluble when in powder in hydrochloric and nitric acids.

Found in gypsum. Brunswick, Holstein, France.

Rhodizite.—$3CaO + 4BO^3$. **cubic**. H 8·0 G 3·416. Translucent. *Lus.* vitreous. *Col.* white, yellowish, grayish. Pyroelectric. B. fusible with difficulty.

Found with red tourmaline and quartz, in the Ural.

Datholite.—*Siliceous Borate of Lime, Botryolite, Humboltite, Esmarkite, Prismatic Dystome Spar.*—$(2CaO + SiO^2) + (BO^3 + SiO^2) + HO$. **prismatic**. H 5·5 G 2·8 – 3·0. Case 39. *Frac.* imperfect conchoidal. Translucent, transparent. *Lus.* vitreous. *Col.* white, inclining to green, yellow, and gray. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in slate, sandstone, serpentine, and greenstone. The Hartz, Bavaria, the Tyrol, Tuscany, Italy, Connecticut, New Jersey, and Scotland.

Tourmaline.—*Schorl, Aphrizite, Rubellite, Indicolite.*—**rhombohedral**. H 7·0 – 7·5 G 3·0 – 3·3. Case 40. *Frac.* imperfect conchoidal. Transparent, almost opaque. *Lus.* vitreous. *Col.* colourless, gray, yellow, green, blue, red, brown, black.

Str. white. Pyroelectric. B. fusible. Decomposed by concentrated sulphuric acid after fusion.

Found in gneiss, granite, mica slate, pebbles and sand of rivers. The Grimsel, Saxony, Moravia, Massachusetts, Siberia, Bothnia, Carinthia, Ceylon, Pegu, Madagascar, Brazils, the Tyrol, Devonshire, Cornwall, Sweden, Norway, Greenland, the Pyrenees, Banffshire, Elba. The black opaque varieties are called *schorl*, the blue crystals from Sweden *indicolite*, and the red varieties *rubellite*, or *siberite*. The specimen of rubellite in the British Museum, presented by the King of Ava to Colonel Symes, has been valued at £500. The blue, green, and brown transparent crystals are much prized, on account of their property of polarizing light, when cut in thin plates parallel to the axes of the hexagonal prism. Some of the transparent varieties are used as gems, and are sometimes sold for emeralds, topaz, and red sapphire. The yellow tourmaline is quite as valuable as the topaz; but the green and red are inferior to the emerald and sapphire. The specific gravity affords a ready test for their discrimination.

Axinite.—*Prismatic Axinite, Thumite, Thumerstein.*—**anorthic**. H 6·5 — 7·0 G 3·29 — 3·30. Case 40. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* brown, blue, gray. Brittle. Acquires vitreous electricity by friction, pyroelectric. B. fusible. Decomposed by hydrochloric acid after fusion, leaving a jelly of silica.

Found in granite, dionite, diabase, gneiss, mica slate, and clay slate. Dauphiné, Cornwall, the Pyrenees, Savoy, St. Gotthardt, the Tyrol, Saxony, Norway, Sweden, the Ural, the Hartz. Though susceptible of a high polish, it wants the brilliancy requisite for an ornamental stone.

Natron.—*Carbonate of Soda, Hemiprismatic Natron Salt.*—$(Na\,O + CO^2) + 10\,HO$. **oblique**. H 1·0 — 1·5 G 1·423. Case 41. *Frac.* conchoidal, transparent, semi-transparent. *Lus.* vitreous. *Col.* colourless, white, yellow, gray. *Str.* white. Sectile. Taste alkaline, pungent. B. fusible. Soluble in water.

Hungary, the Asiatic Steppes, Bohemia, Vesuvius, Ætna, Teneriffe, Guadaloupe, Egypt.

Trona.—*Prismatoidal Trona Salt, Striated Soda.*—$(2\,Na\,O + 3\,CO^2) + 4\,HO$. **oblique**. H 2·5 G 2·112. Case 41. *Frac.* uneven. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray. *Str.* white. Brittle. Taste alkaline. B. fusible. Soluble in water.

Found on the banks of natron lakes, and under a stratum of clay. Egypt, Fezzan, Columbia.

Thermonatrite.—*Prismatic Carbonate of Soda.*—$Na\,O + CO^2 + HO$. **prismatic**. H 1·5 G 1·5 — 1·6. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellowish. *Str.* white. Sectile. Taste pungent, alkaline.

Found with natron. Debreczin, Vesuvius, Egypt, Asia, and America. Supposed to be the *nitre* of the Old Testament.

Alstonite.—*Right Prismatic Baryto-calcite.*—$(BaO + CO^2) + (Ca\,O + Co^2)$ **prismatic**. H 4·0 — 4·5 G 3·65 — 3·70. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, grayish, white. *Str.* white. Soluble in acids with effervescence.

Found in veins with galena, Alston Moore and Fallowfield.

Baryto-Calcite.—*Hemiprismatic Hal-Baryta.*—$(Ba\,O + CO^2) + (Ca\,O \quad CO^2)$. **oblique**. H 4·0 G 3·6 — 3·7. Case 41. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* grayish, yellowish, or greenish-white. *Str.* white Brittle. B. infusible. Soluble with effervescence in hydrochloric and in nitric acids.

Found in mountain limestone. Cumberland.

Witherite.—*Carbonate of Baryta, Diprismatic Hal-Baryta.*—Ba O + C O^2. **prismatic.** H 3·0 – 3·5 G 4·2 — 4·4. Case 41. *Frac.* uneven. Semi-transparent, semi-translucent. *Lus.* vitreous. *Col.* white inclining to yellow, gray, green, and red. Brittle. B. fusible. Soluble with effervescence in dilute hydrochloric acid.

Found in transition rocks, granite and porphyry. Lancashire, Cumberland, Durham, Westmoreland, Shropshire, Flintshire, Styria, Saltzburg, Silesia, Hungary, Siberia, Sicily, Chili. Distinguished from *barytes* by its solubility in acids.

Strontianite.—*Carbonate of Strontian, Peritomous Hal-Baryta.* Sr O + C O^2. **prismatic.** H 3·5 G 3·59 — 3·65. Case 41. *Frac.* uneven. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, green. *Str.* white. Brittle. B. fusible on the edges. Soluble with effervescence in hydrochloric and nitric acids.

Found in limestone, clay, ironstone, basalt. Strontian, Leadhills, Yorkshire, Freiberg, Clausthal, Saltzburg, Westphalia, the Grisons, Giant's Causeway, Poland, New York, Peru. Strontia and all its combinations possess the property of giving a red colour to flame, and is therefore used for fire-works.

Aragonite.—*Prismatic Lime Haloide, Tarnowitzite, Satin Spar, Needle Spar, Igbite.* —Ca O + C O^2. **prismatic.** H 3·5 — 4·0 G 2·93 — 3·01. Cases 41 and 42. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, green, blue. *Str.* grayish-white. B. infusible. Soluble with effervescence in nitric and hydrochloric acids.

Found in gypsum, basaltic rocks, beds of brown iron ore, serpentine, lava, and deposited by hot springs. Aragon, Valencia, Bohemia, Baden, Hessia, Auvergne, the Tyrol, Hungary, Siberia, Greenland, Thuringia, the Hartz, Styria, Piedmont, Vesuvius, Iceland, Carlsbad, Cumberland, Carinthia, Devonshire, Buckinghamshire, Leadhills, Galloway. This mineral is named from Aragon, a province of Spain. The corralloid varieties which occur in beds of iron ore are called *Flos ferri;* and the massive, silky, fibrous variety derives the name of *Satin spar* from its appearance. Aragonite is distinguished from calcite by the form of its cleavage, and by flying into powder on being exposed to heat. When carbonate of lime crystallizes from its solution in boiling water containing carbonic acid, it forms crystals of *Aragonite;* if, however, it crystallizes from the same solution at the ordinary temperature of the atmosphere, it takes the form of *calcite.*

Calcite.—*Carbonate of Lime, Rhombohedral Lime Haloide.*—Ca O + C O^2. **rhombohedral.** H 3·0 G 2·69 — 2·75. Cases 42—46. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, blue, green, yellow, red, brown, black. *Str.* white. Brittle. B. infusible. Soluble with effervescence in hydrochloric and nitric acids.

Found in limestone and almost every kind of rock, also in cavities of amygdaloidal rocks. Iceland, the Hartz, Derbyshire, Cumberland, Prague, Carinthia, Bohemia, Saxony, France, United States, Thuringia. The beautiful transparent varieties from Iceland are called Iceland spar, and are remarkable for the beautiful manner in which they exhibit the properties of double refraction.

Schiffer Spath or *Slate Spar,* a lamellar variety of carbonate of lime, is found in Saxony, Bohemia, Norway, Cornwall, Scotland, Wicklow.

Granular Limestone and *Statuary Marble* consists of minute crystals of carbonate of lime. This substance is valued according as it is free from flaws, colour, and is capable of receiving a good polish. Naxos, Paros, Tenedos, Carrara. Marbles variously coloured by foreign substances form the greater part of the transition rocks.

Oolite or *Roestone* consists of an aggregation of minute globular masses of carbonate of lime. The Portland and Bath stones are varieties of oolite.

Stalactites are pendulous masses of carbonate of lime, hanging from the roofs of caverns, and formed by the water trickling through the roof charged with carbonate of lime.

Tufa or *Calcareous Tuff* is a porous variety of limestone, deposited by calcareous springs. It possesses the valuable property of hardening on exposure to the air.

Chalk is a massive opaque carbonate of lime, consisting almost entirely of minute fossil infusoria.

Ankerite.—*Paratomous Lime Haloide, Rhoe Wand, Wandstein.*—**rhombohedral.** H 3·5 — 4·0 G 3·040 — 3·085. *Frac.* uneven. Translucent. *Lus.* vitreous. *Col.* yellowish, white, gray, brown. *Str.* white. Brittle. Soluble with effervescence in nitric acid.

Found in beds of mica slate. Styria. Highly prized as an iron ore and as a flux for smelting.

Dolomite—*Bitter Spar, Pearl Spar, Tharandite, Brown Spar, Miemite, Rhomb Spar, Magnesian Carbonate of Lime, Magnesian Limestone, Macrotypous Lime Haloide.*—$CaO + CO^2$, $MgO + CO^2$. **rhombohedral.** H 3·5 – 4·5 G 2·80 — 2·95. Case 47. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, green, yellow, red, blue, brown, gray, black. *Str.* grayish-white. Brittle. B. infusible. Soluble in hydrochloric acid.

Forms rocks by itself, and occurs in beds in other rocks. The Apennines, the Tyrol, Switzerland, Piedmont, Tuscany, Saxony, Bohemia, Hungary, the Hartz, Norway, Sweden, Scotland, England. Better adapted for mortar than common limestone, as it absorbs less carbonic acid. The white marble of Paros and Iona belong to this species. It admits of being cut and polished, and is said to be durable.

Magnesite.—*Carbonate of Magnesia.*—$MgO + CO^2$. **rhombohedral.**—H 4·5 — 5·0 G 2·88 — 3·02. Case 48. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* colourless, yellow, brown, black. *Str.* white. B. infusible. Soluble in dilute sulphuric acid, and in nitric acid. Adheres to the tongue.

Found in serpentine. Sweden, Silesia, Moravia, Styria, the Tyrol, East Indies, Spain, America.

Hydromagnesite.—*Native Magnesia, Hydrocarbonate of Magnesia. Lancasterite.*—$3(MgO + CO^2) + (MgO + 4HO)$. **oblique.** H 3·5 G 2·14 —2·35. Case 47. Faintly translucent. *Lus.* pearly. *Col.* white, green. *Str.* white. B. infusible. Soluble in hydrochloric acid.

Found in earthy masses in serpentine. New Jersey, New York, Shetland Islands. Resembles talc, but distinguished from it by its hardness and specific gravity.

Gaylusite.—*Hemiprismatic Kouphone Haloide.*—$(NaO + CO^2) + (CaO + CO^2) + 5HO$. **oblique.** H 2·5 G 1·928 — 1·950. Case 48. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow. *Str.* white. Brittle. B. fusible. Soluble in nitric or hydrochloric acid.

Found in crystals in a bed of clay at Lagunilla in Columbia; it is called *clavos* or nails by the natives, from the appearance of its crystals.

Chalybite.—*Spathose Iron, Sparry Iron, Carbonate of Oxide of Iron, Sphärosiderite, Siderite.*—$FeO + CO^2$. **rhombohedral.** H 3·5 – 4·5 G 3·70 — 3·92. Case 48. *Frac.* imperfect conchoidal. Transparent, translucent. Opaque. *Lus.* vitreous. *Col.*

yellow, brown, gray, white, red. *Str.* yellowish-white. Brittle. Soluble in warm nitric acid.

Found in gneiss, slate and limestone, in metallic veins, and in cavities in trap rocks. The Hartz, Nassau, Styria, Carinthia, Westphalia, the Pyrenees, Bohemia, Saxony, Devonshire. *Clay Ironstone*, which is a mixture of chalybite and clay, is found in Staffordshire, South Wales, Bohemia, Moravia, Silesia, Poland, United States. A very valuable iron ore. The Styrian steel is obtained from the iron made from it.

Diallogite.—*Carbonate of Manganese, Red Manganese, Rhodocrosite.*—$Mn\,O + C\,O^2$. **rhombohedral.** H 3·5 — 4·5 G 3·43 — 3·63. Case 48. *Frac.* uneven. Slightly translucent. *Lus.* vitreous. *Col.* rose red, flesh red. *Str.* white. Brittle. B. infusible. Soluble in hydrochloric acid.

Found in gneiss, porphyry, and hematite. Saxony, Hungary, Transylvania, the Hartz, Switzerland, Ireland. Distinguished from manganese spar by its hardness. Some varieties become brown by exposure to air.

Calamine.—*Carbonate of Zinc, Zinc Spar, Rhombohedral Zinc Baryta, Smithsonite.*—$Zn\,O + C\,O^2$. **rhombohedral.** H 5·0 G 4·34 — 4·45. Case 49. *Frac.* uneven. Semi-transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, green, brown. *Str.* white. Brittle. B. infusible. Soluble in hydrochloric acid.

Found in the slate, transition, coal and oolite formations. Westphalia, Silesia, Carinthia, the Banat, Poland, Hungary, Servia, the Altai, Siberia, France, Belgium, United States, Scotland, Somersetshire, Derbyshire, Cumberland. Zinc is extracted from this ore.

Buratite.—*Aurichalcite, Orichalcite.*—$(3\ Zn\,O + C\,O^2) + (2\,Cu\,O + C\,O^2) + 3\,H\,O$. H 2·0. Case 49. Translucent. *Lus.* pearly. *Col.* green. Soluble in hydrochloric acid.

Found in the Ural and in France.

Selbite.—*Carbonate of Silver, Gray Silver.*—Amorphous. *Frac.* uneven, earthy. *Lus.* dull. *Col.* gray. Soft. Sectile. B. fusible. Soluble in nitric acid.

Found in the Black Forest and Mexico.

Cerussite.—*Carbonate of Lead, Lead Spar, Diprismatic Lead Baryta.*—$Pb\,O + C\,O^2$. **prismatic.** H 3·5 G 6·4 — 6·6. Case 49. *Frac.* conchoidal. Transparent, translucent. *Lus.* adamantine. *Col.* colourless, white, gray, green, blue. *Str.* white. Brittle. B. fusible. Decomposed by hydrochloric acid.

Found in crystals, masses, and pseudomorphous, after other substances. Bohemia, Carinthia, Hungary, Saxony, the Hartz, Silesia, Westphalia, France, the Altai, Siberia, Devonshire, Cornwall, Cumberland, Derbyshire, Scotland. Valuable as an ore of lead; distinguished from sulphate of lead by its crystals being usually macled.

Agnesite.—*Bismutite, Carbonate of Bismuth.*—$4\ Bi\ O^3 + 3\ CO^2 + 4\,H\,O$. Amorphous. H 4·0 — 4·5 G 6·909 — 7·670. Case 49. *Frac.* conchoidal. Opaque. Translucent on the edges. *Lus.* vitreous, dull. *Col.* green, yellow. *Str.* gray or white. B. fusible. Soluble in hydrochloric acid.

Found investing other minerals, and in pseudomorphous crystals. Schneeberg, Cornwall.

Lanthanite.—*Carbonate of Cerium.*—$3\ La\ O + C\,O^2 + 3\ HO$. **pyramidal.** H 2·5 — 3·0. Case 49. *Lus.* pearly. *Col.* white, gray, yellow. *Str.* white. Soluble in acids.

Found with cererite at Riddarhytta, in Sweden. An extremely rare mineral.

Parisite.—*Mussonite, Carbonate of Cerium Lanthanium and Didymium.*—**rhombohedral.** H 4·5 G 4·35. Case 49. *Frac.* small conchoidal. *Lus.* vitreous. *Col.* brown, yellow. *Str.* yellowish-white. B. infusible. Soluble with difficulty in hydrochloric acid.

Found in the emerald mines of Muzo, in New Granada.

Breunnerite.—*Brachytypous Lime Haloide, Carbonate of Magnesia and Iron.* Mg O + C O^2. **rhombohedral.** H 4·0 — 4·5 G 3·0 — 3·2. Case 49. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellow, brown. *Str.* grayish-white. Brittle. B. infusible. Soluble in acids.

Found in chlorite, talc, sometimes in serpentine, rarely in gypsum. The Tyrol, St. Gotthardt, Norway, United States, Shetland. Distinguished from dolomite by its crystallization, hardness, and specific gravity.

Mesitine.—*Mesitine Spar, Pistomesite.*—**rhombohedral.** H 3·5 — 4·0 G 3·35 — 3·42. Case 49. Transparent, translucent. *Lus.* vitreous. *Col.* gray, yellow, green. *Str.* white. Brittle. B. infusible. Soluble in hydrochloric acid.

Found with quartz and hematite, Piedmont and Saltzburg.

Chessylite.—*Blue Carbonate of Copper, Azurite, Lasur Malachite, Hemiprismatic Azure Malachite.*—(2 Cu O + C O^2) + (Cu O + H O). **oblique.** H 3·5 — 4·0 G 3·766 — 3·831. Case 50. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* azure-blue, passing into blackish-blue. *Str.* blue. Brittle. B. fusible. Soluble in nitric acid.

Found in veins with green carbonate and red oxide of copper. Chessy, the Altai, the Banat, Servia, Poland, the Tyrol, Bohemia, Spain, Cornwall, Cumberland, Scotland, Siberia, Thuringia, Hessia, Silesia, Chili. A valuable ore of copper when found in sufficient quantity.

Malachite.—*Green Carbonate of Copper.*—(Cu O + C O^2) + (Cu O + H O). **oblique.** H 3·5 — 4·0 G 3·71 — 4·01. Case 51. *Frac.* conchoidal. Transparent, or translucent on the edges. *Lus.* adamantine. *Col.* green. *Str.* green. Brittle. B. partly infusible. Soluble in nitric acid.

Found in copper mines. Chessy, Spain, Prussia, Thuringia, the Tyrol, the Banat, Poland, Siberia, Cornwall, Wales, Ireland, Australia. Malachite has been divided into the *fibrous* and *massive*. The crystallized variety is extremely rare, and only found in minute transparent twins coating the cavities of the fibrous kinds. It is a valuable ore of copper, but is most prized by the lapidary on account of the beauty of its colour, and the high polish of which it is susceptible. The valuable vases and tables of malachite manufactured at St. Petersburgh are mostly formed of thin plates of this substance skilfully veneered.

Nitre.—*Nitrate of Potash, Saltpetre.* K O + N O^5. **prismatic.** H 2·0 G 1·933. Case 52. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow. *Str.* white. Soluble in water.

Found as an efflorescence on the surface of the earth. Hungary, Podolia, Spain, Italy, France, Arabia, East Indies, Calabria, Virginia, the Brazils. It is also procured artificially from the decomposition of animal and vegetable matter. Used in the manufacture of gunpowder and of nitric acid.

Nitratine.—*Nitrate of Soda.*—(Na O + N O^5). **rhombohedral.** H 1·5 — 2·0 G 2·096. Case 52. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous, *Col.* colourless, white, gray, brown. *Str.* white. B. fusible. Soluble in water.

Found in crystals in beds several feet thick, with clay and sand, in the district of Tarapaca in Peru.

Mirabilite.—*Sulphate of Soda, Glauber Salt.*—Na O + S O^3 + 10 H O. **oblique.** H 1·5 — 2·0 G 1·481. Case 52. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* colourless, white. *Str.* white. Sectile. B. fusible. Soluble in water.

Found in salt springs as an efflorescence on the soil, and dissolved in mineral waters. Austria, Saltzburg, Bohemia, the Tyrol, Hungary, Spain, the Hartz, Switzerland, Siberia, Egypt. Employed in some countries as a substitute for soda in the manufacture of glass.

Astrakhanite.—(Na O + S O^3) + (Mg O + S O^3) + 4 H O. Transparent. *Col.* colourless. Efflorescent. Soluble in water.

Found in prismatic crystals in the salt lakes of Astrakhan.

Glauberite.—*Anhydrous Sulphate of Soda and Lime, Hemiprismatic Brythine Spar, Brongniartin.*—(Na O + S O^3) + (Ca O + S O^3). **oblique.** H 2·5 — 3·0 G 2·75 — 2·85. Case 52. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, red. *Str.* white. Brittle. B. fusible. Partially soluble in water.

Found in rock salt. Spain, Bavaria, Atacama, Chili.

Thenardite.—(Na O + S O^3). **prismatic.** H 2·5 G 2·67 — 2·73. Case 52. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white. B. fusible. Soluble in water.

Found in crystals in the brine springs at Salinas d'Espartinas, near Madrid.

Glaserite.—*Sulphate of Potash, Arcanite.*—K O + S O^3. **prismatic.** H 2·5 — 3·0 G 2·689 — 2·709. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* colourless, white, yellow, gray. *Str.* white. Brittle. B. fusible. Soluble in water.

Found on the lava of Vesuvius and in some springs.

Mascagnine.—*Sulphate of Ammonia.*—N H^4 O + S O^3. **prismatic.** H 2·0 — 2·5 G 1·68 — 1·78. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow. *Str.* white. Sectile. B. volatilizes. Soluble in water.

Found associated with sulphur, with volcanic productions, and in coal mines. Vesuvius, Etna, Solfatara, Lipari, Aveyron, Staffordshire.

Baryte.—*Sulphate of Barytes, Heavy Spar, Hepatite, Prismatic Hal-Baryta.*—Ba O + S O^3. **prismatic.**—H 3·0 — 3·5 G 4·35 — 4·59. Cases 52 and 53. *Frac.* conchoidal. Transparent or translucent. *Lus.* vitreous. *Col.* colourless, white, gray, blue, yellow, red. *Str.* white. Brittle. B. fusible with difficulty. Insoluble in hydrochloric acid.

Found in beds and veins in various formations. Westphalia, the Hartz, Saxony, Bohemia, Hungary, the Tyrol, Transylvania, France, Baden, Hessia, Cumberland, Surrey, Staffordshire, Derbyshire. *Hepatite or fetid baroselenite* is a variety of *baryte*, containing bitumen. Norway, The *Cawk* of Staffordshire and Derbyshire is an opaque, massive variety of baryte. The white varieties are ground and used as paint. All the salts of barytes but one are violent poisons. The nitrate of barytes is used for producing a green flame.

Celestine.—*Sulphate of Strontia, Prismatic Hal-Baryta.*—Sr O + S O^3. **prismatic.** H 3·0 — 3·5 G 3·85 — 4·0. Case 53. *Frac.* imperfect conchoidal. Transparent, translucent. Opaque. *Lus.* vitreous. *Col.* colourless, white, gray, blue, flesh-red. Brittle. B. fusible. Insoluble in hydrochloric acid.

Found in sulphur mines, limestones, metallic veins, and in fossils. Sicily, France, Hungary, Lake Erie, Jena, Bristol, Switzerland, Spain, Edinburgh. Distinguished from baryte *by its specific gravity.*

Gypsum.—*Sulphate of Lime, Selenite.*—Ca O + S O^3 + 2 H O. **oblique.** H 1·5 — 2·0 G 2·28 — 2·33. Case 54. *Frac.* flat, conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, red, yellow, blue, gray. *Str.* white. Sectile. B. fusible. Very slightly soluble in water and acids.

Found in new red sandstone, in older rocks, clay, in sulphur, and in fossils. Brunswick Hessia, Thuringia, the Tyrol, Switzerland, Paris, Oxford, Sicily, Spain, Siberia, Yorkshire, Cheshire, Derbyshire, Nottinghamshire, Scotland, the United States. The large blocks are wrought into alabaster figures and ornaments. Calcined and powdered it forms *plaster of Paris*. Distinguished by its softness from limestone.

Karstenite.—*Anhydrite, Anhydrous Sulphate of Lime, Cube Spar, Muriacite.*—Ca O + S O^3. **prismatic.** H 3·0 — 3·5 G 2·85 — 3·05. Case 54. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, red, blue. *Str.* grayish-white. Brittle. B. fusible with difficulty. Slightly soluble in water and hydrochloric acid.

Found in beds and veins, and in clay. Styria, the Tyrol, Switzerland, Savoy, Italy, New York, the Hartz, Sweden.

Epsomite.—*Sulphate of Magnesia, Epsom Salt, Prismatic Bitter Salt.*—Mg O + S O^3 + 7 H O. **prismatic.** H 2·0 — 2·5 G 1·7 — 1·8. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, red. *Str.* white. Taste bitter and saline. B. fusible. Soluble in water.

Found as an efflorescence and in mineral springs. Hungary, Bohemia, the Tyrol, Spain, South Africa, Milo, Sedlitz, Epsom, Chili. Is used for pharmaceutical purposes, but is generally obtained by manufacturing chemists from magnesian limestone, and other sources.

Halotrichite.—*Alunogen, Feather Alum, Hair Salt.*—(Al O^3 + S O^3) + 18 H O. H 2. Case 55. *Frac.* uneven. Translucent on the edges. *Lus.* dull. *Col.* white, gray, yellow. B. fusible. Soluble in water.

Found in alum shale, coal mines, and volcanic craters. Thuringia, Dresden, Bonn, Columbia, Bogota, Quito, Chili, Milo, Neapolitan Solfatara.

Polyhalite.—(K O + S O^3) + (Mg O + S O^3) + 2 (Ca O + S O^3) + 2 H O. **prismatic.** H 3·5 G 2·73 — 2·78. Case 55. *Frac.* uneven. Translucent. *Lus.* waxy. *Col.* red. *Str.* white. Brittle. B. fusible. Partially soluble in water.

Found in Styria, Austria, and Bavaria. Derives its name from πολυς *many*, and αλς *salt*, on account of the variety of its saline constituents.

Goslarite.—*Sulphate of Zinc, White Vitriol.*—Zn O + S O^3 + 7 H O. **prismatic.** H 2·0 — 2·5 G 1·9 — 2·1. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous, *Col.* colourless, white, red, blue. *Str.* white. Brittle. B. infusible. Soluble in water.

Found in old mines. Sweden, the Hartz, Hungary, France, Spain, Holywell, Cornwall. Is not found in great abundance in nature, but is prepared artificially. Used in medicine and in dyeing. A permanent white colour. *Zinc white* is prepared from it.

Bieberite.—*Sulphate of Cobalt, Cobalt Vitriol.* — Co O + S O^3 + 7 H O. **oblique.** Case 55. *Frac.* uneven. Translucent, opaque. *Lus.* vitreous. *Col.* red. *Str.* reddish-white. Soluble in water.

Found in old mines. Bieber, Siegen, and Saltzburg.

Melanterite.—*Sulphate of Iron, Green Vitriol.*—Fe O + S O^3 + 7 H O. **oblique.**

H 2·0 G 1·8 — 1·9. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* green, white. *Str.* white. Rather brittle. Soluble in water.

Found in old mines. Bavaria, Sweden, the Hartz, Saxony, Hungary. Used in dyeing and in the manfacture of sulphuric acid, ink, and Prussian blue.

Botryogen.—*Red Sulphate of Iron, Red Vitriol.*—**oblique.** H 2·0 — 2·5 G 2·039. Case 55. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* red, yellow. *Str.* yellow. Sectile. B. infusible. Soluble partially in boiling water.

Found at Fahlun in Sweden. Derives its name from βοτρυς *a bunch of grapes*, because it frequently occurs in the form of globules with a crystalline surface.

Copiapite.—A hydrous sulphate of iron. Six-sided prisms. Translucent. *Lus.* pearly. *Col.* yellow.

Found at Coquimbo in Chili.

Coquimbite.—2 Fe O^3 + 3 S O^3 + 9 H O. **rhombohedral.** H 2·0 — 2·5 G 2·0 — 2·1. *Frac.* conchoidal, uneven. Translucent. *Col.* white, blue, green. Soluble in water.

Found in green felspar. Coquimbo.

Blue Vitriol.—*Sulphate of Copper, Cyanose.*—Cu O + S O^3 + 5 H O. **anorthic.** H 2·5 G 2·19 — 2·30. Case 55. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* vitreous. *Col.* blue. *Str.* white. Rather brittle. B. fusible. Soluble in water.

Found in mines, and in the water of mines. Sweden, Hungary, Cornwall, Anglesea, Wicklow, Seville, Cyprus, Siberia. After being purified, used in the manufactures, for dyeing and electrotyping.

Brochantite.—*Prismatic Dystome, Malachite, Krisuvigite.*—(Cu O + S O^3) + 3 (Cu O + H O). **prismatic.** H 3·5 — 4·0 G 3·87 — 3·9. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* green. *Str.* green. B. infusible. Soluble in acids.

Found in Siberia, Hungary, Iceland, France.

Lettsomite.—*Velvet Copper Ore, Kupfersammterz.*—2 S O^2 + 6 Cu O + Al O^3 + 12 H O. Case 55. Capillary crystals. Translucent. *Lus.* pearly. *Col.* smalt blue.

Found with malachite at Moldawa, in the Banat, coating the cavities of an oxide of iron. It is extremely rare.

Linarite.—*Cupreous Sulphate of Lead, Diplogenic Lead Baryta.*—(Pb O + S O^3) + (Cu O + H O). **oblique.** H 2·5 — 3·0 G 5·3 — 5·43. Case 55. *Frac.* conchoidal. Feebly translucent. *Lus.* adamantine. *Col.* deep blue. *Str.* pale blue. Slightly brittle.

A rare mineral. Found at Leadhills, in Scotland, Spain, and Cumberland.

Johannite.—*Subsulphate of Uranium, Hemiprismatic Euchlore Salt.*—**oblique.** H 2·0 — 2·5 G 3·191. Case 55. *Frac.* imperfect conchoidal. Semi-transparent. *Lus.* vitreous. *Col.* green. *Str.* green. Sectile. Taste slightly bitter. Soluble in hydrochloric acid.

A very rare mineral. Found at Joachimsthal, in Bohemia.

Anglesite.—*Sulphate of Lead, Prismatic Lead Baryta, Lead Vitriol.*—Pb O + S O^3. **prismatic.** H 3·0 G 6·26 — 6·3. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* adamantine. *Col.* colourless, yellow, gray, brown, blue, green. *Str.* white. Brittle. B. fusible. Slightly soluble in nitric acid.

Produced by the decomposition of galena. Baden, Siegen, Silesia, the Hartz, Spain, Siberia, Massachusetts, Missouri, Anglesea, Cornwall, Scotland. It sometimes contains silver.

Lanarkite.—*Sulphato-Carbonate of Lead, Prismatoidal Lead Baryta.*— $(Pb\ O + S\ O^3) + (Pb\ O + C\ O^2)$. Thin plates. H 2·0 – 2·5 G 6·8 – 7·0. Case 55. Transparent. *Lus.* adamantine. *Col.* greenish or yellowish-white. *Str.* white. Sectile. B. fusible. Partially soluble in nitric acid.

Found at Leadhills in Scotland, and in Siberia.

Susannite.—$(Pb\ O + S\ O^3) + 3\ (Pb\ O + C\ O^2)$. **rhombohedral.** H 2·5 G 6·55. Case 55. Transparent, translucent. *Lus.* resinous, adamantine. *Col.* white, green, yellow, black. *Str.* white. B. fusible. Partially soluble in nitric acid.

Found at Leadhills in Scotland, and Moldawa, in the Banat.

Caledonite.—*Cupreous Sulphato-Carbonate of Lead, Paratomous Lead Baryta.*— **prismatic.** H 2·5 – 3·0 G 6·4. Case 55. *Frac.* uneven. Transparent, translucent. *Lus.* resinous. *Col.* blue. *Str.* blue. Rather brittle. B. fusible. Partially soluble in nitric acid.

A beautiful mineral. Found at Leadhills in Scotland.

Leadhillite.—*Sulphato-Tri-carbonate of Lead, Axotomous Lead Baryta.*—$(Pb\ O + S\ O^3) + 3\ (Pb\ O + C\ O^2)$. **prismatic.** H 2·5 G 6·26 – 6·43. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* resinous. *Col.* white, yellow, gray, green, brown. *Str.* white. Rather brittle. B. fusible. Partially soluble in nitric acid.

Found at Leadhills in Scotland.

Alum.—$(K\ O + S\ O^3) + (Al\ O^3 + 3\ S\ O^3) + 24\ H\ O$. **cubic.** H 2·0 – 2·5 G 1·9 — 2·0. Case 55. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* white. *Str.* white. Soluble in water.

Found as an efflorescence on aluminous rocks and lava. Lipari Islands, Sicily, St. Michael, Thuringia, Norway, Yorkshire. Used as a medicine, in dyeing, and in the manufacture of leather, paper, &c.

Soda Alum.—$(Na\ O + S\ O^3) + (Al\ O^3 + 3\ S\ O^3) + 24\ H\ O$. **cubic.** H 2·0 – 2·5 G 1·88. Case 55. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* white. *Str.* white. Soluble in water.

Found in the Neapolitan Solfatara, Island of Milo, and Mendoza.

Ammonia Alum.—$(N\ H^3 + H\ O + S\ O^3) + (Al\ O^3 + 3\ S\ O^3) + 24\ H\ O$. **cubic.** H 2·0 – 2·5 G 1·753. Case 55. *Frac.* conchoidal. Translucent. *Lus.* vitreous. *Col.* colourless, grayish-white.

Found in clay and in a bed of brown coal. Thuringia, Bohemia.

Alunite.—*Alum Stone, Rhombohedral Alum Haloide.*—$(K\ O + S\ O^3) + 3\ (Al\ O^3 + S\ O^3) + 6\ H\ O$. **rhombohedral.** H 3·5 – 4·0 G 2·69 – 2·8. Transparent, semi-transparent. *Lus.* vitreous. *Col.* colourless, white, yellow, red, gray. *Str.* white. Brittle. B. infusible. Insoluble in hydrochloric acid.

Found at Tolfa, Tuscany, Hungary, France. The Hungarian varieties are so hard as to be used for mill-stones.

Websterite.—*Subsulphate of Alumina, Aluminite.*—$Al\,O^3 + S\,O^3 + 9H\,O$. H 1·0 G 1·6 – 1·7. Case 55. *Frac.* earthy. Opaque. *Lus.* dull. *Col.* white. *Str.* white. Sectile. B. infusible. Soluble in hydrochloric acid.

Found in botryoidal concretions imbedded in clay, at Halle, Paris, Newhaven.

Garnsdorfite.—*Pissophane.*—A hydrated sulphate of alumina and iron. Amorphous. H 1·5 – 2·0 G 1·922 — 1·981. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* green, brown. *Str.* grayish-white, pale-yellow. Brittle. Soluble in hydrochloric acid.

Found in the alum shale works. Garnsdorf in Thuringia, and Reichenbach in Saxony.

Voltaite.—Cubic. *Frac.* uneven. *Lus.* resinous. *Col.* black, inclining to brown and green. *Str.* grayish-green. Partially soluble in water.

Found in the Neapolitan Solfatara.

Hauyne.—*Dodecahedral Amphigene Spar, Nosean, Lapis Lazuli.*—**cubic.** H 5·5 – 6·0 G 2·25 – 2·5. Case 55. *Frac.* conchoidal. Transparent, opaque. *Lus.* vitreous. *Col.* black, brown, gray, blue. *Str.* light blue. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

The brown and gray variety, *nosean*, is found in volcanic rocks. Laach, in Prussia. The light blue and green, *hauyne*, in volcanic rocks and lava. Laach, the Rhine, France, Rome, Vesuvius. The deep blue, *lapis lazuli*, found mixed with calcite, mica, and pyrite. The Baikal Lake, China, Thibet, Tartary, South America. Valued as an ornamental stone; formerly used as the only source of the beautiful pigment called ultra-marine, which is now manufactured artificially.

Arsenite.—*Oxide of Arsenic, Octahedral Arsenic Acid, Arsenious Acid.*—$As\,O^3$. **cubic.** H 1·5 G 3·699. Case 56. *Frac.* conchoidal. Transparent, opaque. *Lus.* vitreous. *Col.* white. *Str.* white. B. volatilizes. Slightly soluble in water.

Probably produced by the decomposition of ores containing arsenic. Bohemia, Transylvania, Hanau, Alsace, the Hartz, the Pyrenees. Distinguished from pharmacolite, to which it is similar, by being slightly soluble in water. Artificially formed crystals of arsenic not only belong to the cubical system but also to the prismatic, being then isomorphous with valentinite. A very poisonous substance.

Pharmacolite.—*Arseniate of Lime, Hemiprismatic Euclase Haloide.*—$2\,Ca\,O + As\,O^5 + 6\,H\,O$. **oblique.** H 2·0 — 2·5 G 2·64 — 2·73. Case 56. Transparent, translucent. *Lus.* vitreous. *Col.* white, yellow. *Str.* white. Sectile, thin plates flexible. B. volatilizes. Soluble in nitric acid.

Found in Bohemia, Baden, the Hartz, Hessia, Thuringia, Alsace.

Kuhnite.—*Anhydrous Arseniate of Lime, Berzelite.*—$3\,R\,O + As\,O^5$, where R is Ca, Mg, and Mn. H 5·0 – 6·0 G 2·52. Case 56. *Frac.* uneven. *Lus.* waxy. *Col.* white, yellow. Brittle. B. infusible. Soluble in nitric acid.

Found in cleavable masses at Langbanshytta in Sweden.

Haidingerite.—*Diprismatic Euclase Haloide.*—$2\,Ca\,O + As\,O^5 + 4\,H\,O$. **prismatic.** H 2·0 – 2·5 G 2·848. Transparent, semi-transparent. *Lus.* vitreous. *Col.* white. *Str.* white. Sectile. B. fusible. Soluble in nitric acid.

A very rare mineral, supposed to have been found at Joachimsthal in Bohemia, formerly considered a variety of pharmacolite.

Roselite.—An arseniate of lime, magnesia, and cobalt. **prismatic.** H 3·0.

Frac. conchoidal. Translucent. *Lus.* vitreous. *Col.* red. *Str.* white. Soluble in hydrochloric acid.

An extremely rare mineral, found at Schneeberg.

Pharmacosiderite.—*Arseniate of Iron, Hexahedral Lirocone Malachite.*—3 $Fe^2 O^3 + 2 As O^5 + 12 H O$. **cubic.** H 2·5 G 2·9 — 3·0. Case 56. *Frac.* uneven. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* green, yellow, brown. *Str.* light yellow. Pyroelectric. B. fusible. Soluble in hydrochloric acid.

Found in veins of copper ores. Cornwall, France, Nassau, Saxony, United States.

Symplesite.—An arseniate of iron. **oblique.** H 2·5 G 2·957. *Frac.* even. Transparent, translucent. *Lus.* vitreous. *Col.* blue, green. *Str.* bluish-white. B. infusible.

Found at Klein Friesa, near Lobenstein.

Liroconite.—*Octahedral Arseniate of Copper, Lenticular Arseniate of Copper, Chalkophacit.*—**prismatic.** H 2·0 — 2·5 G 2·83 — 2·99. Case 56. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* blue, green. *Str.* the same. B. fusible. Soluble in acids.

Found in Cornwall, Hungary, and Voigtland; very rare on the continent.

Olivenite.—*Rhight Prismatic Arseniate of Copper, Prismatic Olive Malachite.*—$(3 Cu O + As O^5) + (Cu O + H O)$. **prismatic.** H 3·0 G 4·1 — 4·38. Case 56. *Frac.* conchoidal. Semi-transparent, opaque. *Lus.* vitreous. *Col.* green, brown. *Str.* olive-green. B. fusible. Soluble in nitric acid.

Found in Cornwall, Cumberland, the Tyrol, the Banat, Siberia, the Asturias, Chili.

Euchroite.—*Prismatic Emerald Malachite,*—$4 Cu O + As O^5 + 7 H O$. **prismatic.** H 3·5 — 4·0 G 3·35 — 3·45. Case 56. *Frac.* uneven. Transparent, translucent. *Lus.* vitreous. *Col.* pale green. Brittle. Soluble in nitric acid.

A very rare mineral, found in mica slate at Libethen in Hungary; named from ευχροια *beautiful colour.*

Scorodite.—*Martial Arseniate of Copper, Dystomic Fluor Haloide.*—$Fe^2 O^3 + As O^5 + 4 H O$. **prismatic.** H 3·5 — 4·0 G 3·18 — 3·30. Case 56. *Frac.* uneven. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* green, blue, brown. *Str.* white. Rather brittle. B. fusible. Soluble in hydrochloric acid.

Found in Saxony, Bohemia, Carinthia, France, Cornwall, Brazils, Columbia, Siberia.

Erinite.—*Dystomic Habroneme Malachite.*—$5 Cu O + As O^5 + 2 H O$. H 4·5 — 5·0 G 4·043. *Frac.* imperfect conchoidal. Translucent on the edges. *Lus.* dull. *Col.* green. *Str.* green. B. fusible. Soluble in nitric acid.

Found in the county of Limerick associated with arseniate of copper, named *erinite* on account of its characteristic emerald-green colour and its locality.

Cornwallite.—$5 Cu O + As O^5 + 5 H O$. Amorphous. H 4·5 G 4·166. *Frac.* conchoidal. *Col.* green. B. fusible.

Found with olivenite in Cornwall.

Klinoclase.—*Oblique Prismatic Arseniate of Copper, Strahlerz, Aphanese, Abichite.* $(3 Cu O + As O^5) + 3 (Cu O + H O)$. **oblique.** H 2·5 — 3·0 G 4·19 — 4·36. *Frac.* uneven. Translucent, opaque. *Lus.* vitreous. *Col.* green, dark blue. *Str.* verdigris-green. Rather brittle. B. fusible. Soluble in acids.

Found with liroconite. Cornwall, Erzgebirge. The crystals are extremely minute.

Tamarite.—*Rhomboidal Arseniate of Copper, Prismatic Copper Mica, Chalkophyllit.* —**rhombohedral.** H 2·0 G 2·435 – 2·659. *Frac.* conchoidal. Transparent, translucent. *Lus.* pearly or vitreous. *Col.* green. *Str.* green. Sectile. B. fusible. Soluble in acids.

Found in veins of copper ores in the mines of Cornwall.

Tyrolite.—*Kupferschaum, Prismatic Euchlore Mica.*—(5 Cu O + As O^5) + (Ca O + C O^2) + 10 H O. **prismatic.** H 1·0 – 2·0 G 3·02 – 3·098. Case 56. Translucent. *Lus.* pearly or vitreous. *Col.* green, blue. *Str.* the same. Very sectile. In thin leaves flexible. B. fusible. Soluble in hot nitric acid.

Found with ores of copper in fibrous groups of a delicate silky lustre. The Tyrol, Hungary, the Banat, Thuringia.

Konichalcite.—2 (R O + As O^5) + 3 H O, where R is Cu and Ca. H 4·0 – 4·5 G 4·123. *Frac.* splintery. Translucent on the edges. *Lus.* vitreous. *Col.* green. *Str.* green. Brittle.

In reniform masses supposed to have been found at Hinojosa in Andalusia.

Erythrine.—*Red Cobalt, Cobalt Bloom, Arseniate of Cobalt, Prismatic Cobalt Mica.*—3 Co O + As O^5 + 8 H O. **oblique.** H 1·5 – 2·0 G 2·9 – 3·1. Case 56. Transparent, translucent. *Col.* red, gray, green. *Str.* red. Sectile. In thin plates flexible. B. fusible. Soluble in hydrochloric acid.

A beautiful mineral, found in beds and veins with ores of cobalt. Saxony, Bohemia, Thuringia, Hessia, Baden, Dauphiné, the Pyrenees, Norway. When found in sufficient quantity, it is used in the manufacture of smalt. Distinguished from red antimony and red copper ore by yielding a blue glass with borax before the blowpipe.

Kottigite.—Zn O + As O^5 + 8 H O. **oblique.** H 2·5 – 3·0 G 3·1. Translucent. *Lus.* silky. *Col.* red. *Str.* reddish-white. Soluble in acids.

Found with smaltine in the Daniel mine, Schneeberg.

Annabergite.—*Arseniate of Nickel, Nickel Bloom.*—3 Ni O + As O^5 + 8 H O. **oblique.** H 2·5 – 3·0 G 3·078 – 3·131. Case 56. *Col.* green. *Str.* greenish-white. B. fusible. Soluble in nitric acid.

Found in the Hartz, Hessia, Thuringia, Saxony, Bohemia, Dauphiné, Texas.

Vivianite.—*Phosphate of Iron, Blue Iron, Dichromatic Euclase Haloide, Anglarite, Mullicite, Prismatic Iron Mica.*—3 Fe O + P O^5 + 8 H O. **oblique.** H 1·5 – 2·0 G 2·6 – 2·7. Case 57. Transparent, translucent. *Lus.* pearly, vitreous. *Col.* green, blue. *Str.* white, becoming blue on exposure to air, powder of the mineral brown. Sectile. Thin plates flexible. B. fusible. Soluble in hydrochloric acid.

Found in mineral veins and lava, the earthy varieties in peat-bogs. Transylvania, Cornwall, Bavaria, New Jersey, Isle of France, Crimea, Shetland Islands, Isle of Man. Sometimes used as a pigment.

Dufrenite.—*Phosphate of Iron, Grüneisen Stein, Green Iron Earth, Alluaudite.*—**prismatic.** H 4·0 G 3·50 – 3·55. Case 57. Transparent, opaque. *Lus.* vitreous. *Col.* green. *Str.* light green. Brittle. B. fusible. Soluble in hydrochloric acid.

Found at Siegen, Hirschberg in Reuss, and Limoges in France.

Diadochite.—Fe O^3 + 2 P O^5 + 4 (Fe O^3 + S O^3) + 32 H O. Amorphous. H 3·0 G 2·035 – 2·037. Case 57. *Frac.* conchoidal. Translucent, opaque. *Lus.* vitreous. *Col.* yellow, brown. *Str.* white. B. fusible on the edges.

Found in alum shale works near Gräfenthal and Saalfeld in Thuringia.

Zwiselite.—*Eisen Apatite, Iron Apatite.*—R Fl + (R O + P O^5), where R is Fe and Mn. **prismatic.** H 5·0 G 3·97. *Frac.* imperfect conchoidal. Translucent on the edges. *Lus.* resinous. *Col.* clove-brown. *Str.* grayish-white. B. fusible. Soluble in hot hydrochloric acid.

Found in crystalline masses at Zwisel in Bavaria.

Triplite.—*Phosphate of Manganese, Pitchy Iron Ore.*—(4 Fe O + P O^5) + (4 Mn O + P O^5). **prismatic.** H 5·0 — 5·5 G 3·6 — 3·8. Case 57. *Frac.* imperfect, conchoidal. Translucent on the edges, opaque. *Lus.* resinous. *Col.* brownish-black. *Str.* yellowish-gray. Brittle. B. fusible. Soluble in hydrochloric acid.

Found in crystalline masses in granite. France, United States.

Triphyline.—*Tetraphyline, Perowskine.*—(Li O + P O^5) + 6 (3 Fe O + P O^5). **oblique.** H 5·0 G 3·6. Case 57. *Frac.* imperfect conchoidal. Translucent on the edges. *Lus.* resinous *Col.* greenish-gray, spotted with blue. *Str.* grayish-white. B. fusible. Soluble in hydrochloric acid.

Found in granite accompanied by beryl. Rabenstein in Bavaria.

Delvauxine.—*Delvauxite.*—2 Fe^2 O^3 + P O^5 + 24 H O. Amorphous. H 2·5 G 1·85. Case 57. *Frac.* conchoidal. Opaque, translucent on the edges. *Lus.* waxy. *Col.* black, brown, yellow. *Str.* light brown. B. fusible. Soluble in hydrochloric acid.

Found near Visé in Belgium.

Heterosite.—5 R O + [P O^5 + 2 H O, where R is Fe and Mn. **oblique.** H 4·5 — 5·5 G 3·524. Case 57. *Frac.* uneven. Translucent on the edges, opaque. *Lus.* resinous, dull. *Col.* gray, blue, violet. *Str.* red. B. fusible. Soluble in hydrochloric acid.

Found in granite. Hureault, near Limoges in France.

Hureaulite.—*Huraulite.*—5 R O + P O^5 + 8 H O, where R is Mn or Fe. **oblique.** H 5·0 G 2·270. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* yellow, red, brown. B. fusible. Soluble in hydrochloric acid.

Found in granite. Hureault, near Limoges in France.

Libethenite.—*Phosphate of Copper, Prismatic Olivenite, Diprismatic Olive Malachite.*—(3 Cu O + P O^5) + (Cu O + H O) **prismatic.** H 4·0 G 3·6 — 3·8. Case 57. *Frac.* conchoidal. Translucent on the edges. *Lus.* resinous. *Col.* olive-green. *Str.* olive-green. Brittle. B. fusible. Soluble in nitric acid.

Found in mica slate and with malachite. Hungary, the Rhine, Cornwall, the Ural, Chili.

Kryptolite.—*Kryptolith.*—A phosphate of oxide of cerium. G 4·6. Transparent. *Col.* pale yellow. Decomposed by warm hydrochloric acid.

Found in parallel acicular crystals, imbedded in massive apatite, from which it is separated by dissolving the apatite in dilute nitric acid. Arendal in Norway.

Thrombolite.—3 Cu O + 2 P O^5 + 6 H O. H 3·0 — 4·0 G 3·381 — 3·401. *Frac.* conchoidal. Opaque, translucent on the edges. *Lus.* vitreous. *Col.* green. *Str.* green. Brittle. B. fusible.

Found massive with malachite in limestone. Retzbanya in Hungary.

Lunnite.—*Hydrous Phosphate of Copper, Hemiprismatic Dystome Malachite, Phosphochalcite, pseudo malachite.*—$(3\ Cu\ O + P\ O^5) + 3\ (Cu\ O + H\ O)$. **oblique.** H 4·5 — 5·0 G 4·0 — 4·4. *Frac.* conchoidal. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* green. *Str.* green. Brittle. B. fusible. Soluble in nitric acid.

Found in grauwacke-slate. Bavaria, the Rhine, Reuss, the Ural.

Ehlite.—$5\ Cu\ O + P\ O^5 + 3\ H\ O$. H 1·5 — 2·0 G 3·8. *Lus.* pearly. *Col.* green. *Str.* pale green.

Found in reniform and botryoidal masses. The Rhine, the Ural. The *Kupferdiaspore*, a fibrous mineral from Libethen, is supposed to be *ehlite*.

Autunite.—*Yellow Uranite, Uran-mica, Phosphate of Uranium, Pyramidal Euchlore Malachite.*—$(Ca\ O + P\ O^5) + (2\ U^2\ O^3 + P\ O^5) + 8\ H\ O$. **pyramidal.** H 1·0 — 2·0 G 3·0 — 3·2. Case 57. Transparent, translucent. *Lus.* pearly, vitreous. *Col.* yellow, green. *Str* yellow. Sectile. B. fusible. Soluble in nitric acid.

A beautiful mineral, found in granite near Autun, and near Limoges in France. Distinguished from *green mica* by being soluble in nitric acid, and by the brittleness and inelasticity of its thin laminæ.

Torberite.—*Copper Uranite, Chalcolite, Pyramidal Euchlore Malachite, Green Uranite.*—$(Cu\ O + P\ O^5) + (2\ U^2\ O^3 + P\ O^5) + 8\ H\ O$. **pyramidal.** H 2·0 — 2·5 G 3·5 — 3·6. Case 57. Transparent, translucent. *Lus.* pearly and vitreous. *Col.* green. *Str.* green. Rather brittle. Soluble in nitric acid.

Found in slate and granite. Saxony, Bohemia, Bavaria, Cornwall, United States, Belgium.

Xenotime.—*Phosphate of Yttria, Phosphyttrite.*—$3\ Y\ O + P\ O^5$. **pyramidal.** H 4·5 — 5·0 G 4·39 — 4·557. Case 57. *Frac.* splintery. Translucent, translucent on the edges. *Lus.* resinous. *Col.* brown. *Str.* light brown. Brittle. B. infusible. Insoluble in acids.

A very scarce mineral, found in granite. Norway and Sweden.

Wavellite.—*Lasionite, Devonite, Phosphate of Alumina, Prismatic Waveline Haloide.*—$3\ Al\ O^3 + 2\ P\ O^5 + 12\ H\ O$. **prismatic.** H 3·5 — 4·0 G 2·3 — 2·4. Case 57. *Frac.* imperfect conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, gray, green, yellow, brown. *Str.* white. Brittle. B. infusible. Soluble in acids.

Found in slate and granite. Devonshire, Cornwall, Ireland, Scotland, Bohemia, Saxony, Greenland, the Brazils, Pennsylvania.

Gibbsite.—*Hydrargyllite, Felsobanyite.*—$Al\ O^3 + P\ O^5 + 8\ H\ O$, mixed with $Al\ O^3 + 3\ H\ O$. Botryoidal masses. H 3·0 G 2·20 — 2·44. Case 19. Feebly translucent. *Lus.* dull. *Col.* greenish, grayish, yellowish-white. Brittle. B. infusible. Insoluble in hot hydrochloric acid.

In a mine of brown hematite. Richmond, Massachusetts.

Klaprothine.—*Lazulite, Voraulite. Azurite, Blue Spar.*—$2\ (R\ O + P\ O^5) + (Al\ O^3 + 3\ P\ O^5) + 6\ H\ O$, where R is Mg, Fe, and Ca. **oblique.** H 5·0 — 5·5 G 3·0 — 3·121 Case 57. *Frac.* uneven. Transparent, opaque. *Lus.* vitreous. *Col.* blue. *Str.* white. Very brittle. B. infusible. Not soluble in acids.

Found in crystals and massive. Saltzburg, Styria, Lower Austria, the Brazils.

Herderite.—*Prismatic Fluor Haloide.*—An anhydrous phosphate of lime and alumina and hydrofluoric acid. **prismatic.** H 5·0 G 2·985 – 2·99. *Frac.* conchoidal. Transparent. *Lus.* vitreous. *Col.* yellow, white. *Str.* white. Very brittle. B. fusible with difficulty. Soluble in hot hydrochloric acid.

Found very rarely in the tin mines of Ehrenfriedersdorf in Saxony. Its crystals resemble those of that variety of apatite which is called asparagus stone.

Amblygonite.—*Prismatic Amblygonite Spar.*—A phosphate of alumina. **prismatic.** H 6·0 G 3·045 – 3·11. Case 57. *Frac.* uneven. Semi-transparent, translucent. *Lus.* vitreous. *Col.* white, gray, green. *Str.* white. B. fusible. Soluble in sulphuric acid.

Found with tourmaline and topaz in granite. Saxony, Norway.

Turquoise.—*Calaite, Uncleavable Azure Spar.*—A hydrophosphate of alumina. **amorphous.** H 6·0 G 2·62 – 3·0. Case 57. *Frac.* conchoidal. Translucent on the edges, opaque. *Lus.* waxy. *Col.* blue, green. *Str.* greenish-white. Not very brittle. B. infusible. Soluble in hydrochloric acid.

Found in reniform and botryoidal masses. Persia, Thibet, Silesia, Lusatia, Saxony. Sold in the large towns of Persia in small masses, but in great quantities. Cut and polished, it is used for ornamental purposes; when its colour is good, it is greatly valued as a gem. The *occidental turquoise*, from Lower Languedoc, is a very different substance, being bone coloured with phosphate of iron.

Fischerite.—$2\,Al\,O^3 + P\,O^5 + 8\,H\,O$. H 5·0 G 2·46. Transparent. *Lus.* vitreous. *Col.* green. Soluble in sulphuric acid.

Found in small six-sided prisms. The Ural.

Kakokene.—A hydrophosphate of alumina and iron. G 2·336 — 3·38. Case 57. Translucent, opaque. *Lus.* pearly. *Col.* yellow. *Str.* yellow. B. fusible. Soluble in acids.

Found in Bohemia, Bavaria, and the United States. Derives its name from κακος *bad* and ξενος *a guest*, on account of the injurious effect of the phosphorus which it contains on the quality of the iron extracted from it as an ore.

Childrenite.—A phosphate of alumina and iron. **prismatic.** H 4·5 — 5·0. Case 57. *Frac.* uneven. Transparent. *Lus.* vitreous. *Col.* white, yellow, brown. *Str.* white.

Found on slate and quartz. Crinnis in Cornwall and Devonshire.

Wagnerite.—*Hemiprismatic Fluor Haloide.*—$Mg\,F + 3\,Mg\,O + P\,O^5$. **oblique.** H 5·0 — 5·5 G 2·98 — 3·13. Case 57. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* yellow, gray. *Str.* white. Brittle. B. fusible with difficulty. Soluble in hot nitric acid.

An extremely rare mineral, found in crystals with quartz in the crevices of a clay slate rock in the valley of Höllengraben in Saltzburg.

Monazite.—*Mengite, Edwardsite, Eremite.*—A phosphate of the oxides of cerium and lanthanium. **oblique.** H 5·5 G 4·8 – 5·0. Case 57. *Frac.* uneven. Semi-transparent, translucent on the edges. *Lus.* resinous. *Col.* brown, red. *Str.* reddish-yellow. B. fusible with difficulty on the edges. Decomposed by hydrochloric acid.

Found in a mixture of felspar, albite, and mica. Siberia and the United States.

Pyromorphite.—*Phosphate of Lead, Polysphærite, Miesite, Rhombohedral Lead*

Baryta.—(Pb O + Cl) + 3 (3 Pb O + P O^5). **rhombohedral**. H 3·5 — 4·0 G 6·9 — 7·1. Case 57 A. *Frac.* imperfect conchoidal. Semi-transparent. *Lus.* resinous. *Col.* green, brown, yellow, gray. Brittle. B. fusible. Soluble in nitric acid.

Found with galena. Bohemia, Saxony, Baden, the Hartz, France, Hungary, Cornwall, Cumberland, Durham, Yorkshire, Derbyshire, Scotland.

Mimetite.—*Arseniate of Lead, Brachytypous Lead Baryta, Arsenite, Hedyphane.*—Pb Cl + 3 (3 Pb O + As O^5). **rhombohedral**. H 3·5 — 4·0 G 7·18 — 7·28. Case 57 A. *Frac.* imperfect conchoidal. Translucent. *Lus.* resinous. *Col.* green, yellow. *Str.* white. Brittle. B. fusible. Soluble in nitric acid.

Found with galena. Saxony, Baden, Cornwall, Devonshire, Cumberland, France.

Apatite.—*Phosphate of Lime, Talkapatite, Francolite, Moroxite, Asparagus Stone, Phosphorite, Rhombohedral Fluor Haloide.*—Ca Fl + 3 (3 Ca O + P O^5). **rhombohedral**. H 5·0 G 3·18 — 3·21 Case 57 B. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, blue, green, yellow, red, brown. *Str.* white. Brittle. B. fusible with difficulty. Soluble in hydrochloric acid.

Found in granite, gneiss, slate, marble, basalt, and in metallic veins. Spain, the Tyrol, Bohemia, Saxony, Cornwall, Devonshire, Cumberland, Norway, United States, Bavaria, France, the Ural. Named apatite by Werner, from *απαταω to deceive*, on account of the deception it so long caused to the older mineralogists.

Phosgenite.—*Murio Carbonate of Lead, Horn Lead, Corneous Lead.*—Pb Cl + Pb O + C O^2. **pyramidal.** H 3·0 G 6·0 – 6·2. Case 57 B. *Frac.* conchoidal. Transparent-translucent. *Lus.* adamantine. *Col.* colourless, white, gray, yellow, green, brown. *Str.* white. Brittle. B. fusible. Soluble in nitric acid.

A very rare mineral. Found in crystals and globular masses. Matlock in Derbyshire, Cornwall, Massachusetts.

Sodalite.—*Dodecahedral Amphigene Spar, Dodecahedral Zeolite.*—Na Cl + 3 (Na O + Si O^2) + 3 (Al O^3 + Si O^2). **cubic.** H 6·0 G 2·287 — 2·292. Case 57 B. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, yellow, green, gray, blue. *Str.* white. B. fusible. Decomposed by hydrochloric acid, leaving a jelly of silica.

Found in lava, mica slate, and syenite. Sicily, Greenland, Siberia, Norway, United States.

Eudialyte.—*Rhombohedral Almandine Spar.*—2 (R O + Si O^2) + (Zr O + Si O^2) where R is Na, Ca, Fe, and Mn. **rhombohedral.** H 5·0 — 5·5 G 2·84 — 2·95. Case 57B. *Frac.* conchoidal. Translucent on the edges. Opaque. *Lus.* vitreous. *Col.* red. *Str.* white. Slightly brittle. B. fusible. Partly decomposed by hydrochloric acid.

Found at Kangerdluarsuk, in West Greenland.

Pyrosmalite.—*Axotomous Perl Mica.*—15 (Fe O + Si O^2) + 15 (Mn O + Si O^2) + 3 (Fe^2 O^3 + H O) + Fe^2 Cl^3. **rhombohedral**. H 4·0 — 4·5 G 3·0 — 3·2. Case 57 B. *Frac.* uneven. Translucent, opaque. *Lus.* pearly or resinous. *Col.* brown, green. *Str.* lighter than the colour. B. fusible. Decomposed by hydrochloric acid.

A rare mineral. Found in attached and imbedded crystals. Sweden.

—*Fluate of Lime, Octahedral* Fluor Haloide, Fluor Spar.—Ca Fl. **cubic**.

H 4·0 G 3·017 – 3·188. Case 58. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, red, blue, green, black. *Str.* white, Brittle. B. infusible. Soluble in nitric and hydrochloric acids.

Found in veins in tertiary limestone, porphyry, and porphyritic greenstone. Saxony, Bohemia, Baden, Cornwall, Devonshire, Derbyshire, Cumberland, Northumberland, the Banat, Norway, Paris, Renfrewshire, Siberia, United States, Mexico, Vesuvius. The large crystalline masses of Derbyshire presenting a concentric arrangement of various colours, principally blue, is known by the name of *Blue John*. It is turned on the lathe into vases and other ornaments. Fluor is used as a flux for the metallic ores, hence its name from the Latin fluo *to flow*.

Fluellite.—*Fluoride of Aluminium.*—**prismatic.** Case 58. Translucent. *Col.* white.

A very rare mineral, found on granite, at Stenna Gwyn, in Cornwall.

Fluocerite.—*Neutral Fluate of Cerium.*—Ce F + Ce^2 F^3. **rhombohedral.** H 4·0 – 5·0 G 4·7. Case 58. *Frac.* uneven. Opaque. *Lus.* feeble. *Col.* red, yellow. *Str.* yellowish-white. B. infusible.

A very rare mineral, found in albite and quartz. Broddbo, near Fahlun, in Sweden.

Yttrocerite.—*Pyramidal Cerium Baryta.*—Ca F, Y F, Ce F. Case 58. *Frac.* uneven. Translucent, opaque. *Lus.* vitreous. *Col.* purple, blue, red, gray, white. *Str.* white. Brittle. B. infusible. Decomposed by sulphuric acid.

Found in quartz. Sweden, Massachusetts.

Chiolite.—3 Na F + 2 Al F^3. **pyramidal.** H 4·0 G 2·84 – 2·90. Case 58. Transparent, translucent. *Lus.* resinous. *Col.* colourless, white. B. fusible. Decomposed by sulphuric acid.

Found in granite. Miask, in Siberia.

Cryolite.—3 Na F + Al F^3. **prismatic.** H 2·5 – 3·0 G 2·953 – 2·963. Case 58. *Frac.* uneven. Semi-transparent, translucent. *Lus.* vitreous. *Col.* white, yellow, red, brown. *Str.* white. Brittle. B. fusible. Soluble in strong sulphuric acid.

Found in gneiss and granite. West Greenland, Siberia.

Chodnewite—2 Na F + Al F^3. H 4·0 G 3·0 – 3·08. Transparent, translucent. *Lus.* resinous. *Col.* colourless, white. B. fusible. Decomposed by sulphuric acid.

Found in granite. Miask, in Siberia.

Leucophane.—3 (Ca O + Si O^2) + (3 G O + 2 Si O^2) + Na F. **anorthic.** H 3·5 – 4·0 G 2·974. *Frac.* uneven. Transparent, translucent. *Lus.* vitreous. *Col.* yellow, green *Str.* white. Very tough. B. fusible.

Found imbedded in syenite, near Brevig, in Norway.

Topaz.—*Prismatic Topaz, Pycnite, Pyrophysalite.*—2 Al F^3 + 3 Si F^2 + 12 (Al O^3 + Si O^2). **prismatic.** H 8·0 G 3·4 – 3·6. Case 58 A. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* vitreous. *Col.* colourless, white, yellow, red, blue, green. *Str.* white. B. infusible. By ignition, the yellow varieties become red, and the pale yellow colourless, without losing their transparency.

Found in granite, gneiss, and porphyry. Siberia, Moravia, Asia Minor, Saxony, the Brazils, Bohemia, Cornwall, Ireland, Scotland, Sweden, New South Wales. The purest varieties from the Brazils, called the *Goutte d'eau*, when cut in facets, like the diamond, closely resemble it in lustre and brilliance. The topaz is used as an ornamental stone. The Brazilian topaz, which has been made red by exposure to heat, when polished, can be distinguished from the bales ruby only by its becoming electric by friction.

Humite.—*Chondrodite, Hemiprismatic Chrysolite, Macherite, Brucite.*—3 (2 Mg O + Si O^3) + Mg Fl. **oblique.** H 6·5 G 3·10 – 3·20. Case 58 A. *Frac.* uneven. Transparent, translucent. *Lus.* vitreous. *Col.* yellow, brown, gray. *Str.* white. B. infusible. Soluble in hydrochloric acid, leaving a jelly of silica.

Found in limestone and dolomite. Finland, Sweden, United States, Vesuvius.

Salt.—*Muriate of Soda, Chloride of Sodium, Rock Salt.*—Na Cl. **cubic.** H 2·0 G 2·22. Case 59. *Frac.* conchoidal. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, red, green, blue. *Str.* white. Taste, saline. Rather brittle. B. fusible. Soluble in water.

Found widely disseminated, in thick beds and masses in various formations, and as an efflorescence covering large tracts of country. Hungary, Moldavia, Styria, the Tyrol, Bavaria, Wurtemberg, Switzerland, Spain, Cheshire, the Brazils, Mexico, Africa, Arabia. Used extensively for culinary purposes, agricultural and metallurgic operations, also in the manufacture of earthenware, soap, soda, &c.

Sylvine.—*Chloride of Potassium.*—K Cl. **cubic.** G 1·9 – 2·0. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white. Taste, salt, rather bitter. B. fuses and volatilizes. Soluble in water.

Found in crystals, and as an efflorescence. Vesuvius.

Sal Ammoniac.—*Muriate of Ammonia, Octahedral Ammonia Salt, Salmiak.*—N H^4 Cl. **cubic.** H 1·5 – 2·0 G 1·528. Case 59. Transparent, translucent. *Lus.* vitreous. *Col.* colourless, white, gray, yellow, brown, black. *Str.* white. Taste, saline. Very sectile. B. volatilizes without melting. Soluble in water.

Found in crystals and massive. Vesuvius, Etna, Solfatara, Lipari, Bourbon, Iceland, Bucharian Tartary, Himalaya Mountains, France, Scotland, Newcastle. Employed in medicine, metallurgic operations, and in tinning and soldering.

Cotunnite.—Pb Cl. **prismatic.** G 5·238. Case 59. Transparent. *Lus.* adamantine. *Col.* colourless, white. *Str.* white. B. fusible. Soluble in water.

Found in the crater of Vesuvius after the irruption of 1822.

Matlockite.—Pb Cl + Pb O. **pyramidal.** H 2·5 — 3·0 G 7·21. Case 59. *Frac.* uneven. Transparent, translucent. *Lus.* adamantine. *Col.* yellowish. B. fusible.

Found in old heaps in the Cromford level, near Matlock.

Mendipite.—*Kerasine, Peritomous Lead Baryta.*—Pb Cl + 2 Pb O. **prismatic.** H 2·5 – 3·0 G 7·0 – 7·1. Case 59. *Frac.* conchoidal. Translucent. *Lus.* adamantine. *Col.* white, yellow, red, blue. *Str.* white. B. fusible. Soluble in nitric acid.

Found with ores of lead. Mendip Hills, Somersetshire, Westphalia.

Remolinite.—*Muriate of Copper, Smaragdochalcit, Atacamite.*—Cu Cl + 3 (Cu O + H O). **prismatic.** H 3·0 – 3·5 G 3·69 – 3·71. Case 59. *Frac.* conchoidal. Semi-transparent, translucent on the edges. *Lus.* vitreous. *Col.* green. *Str.* green. Rather brittle. B. fusible. Soluble in acids.

Found in veins and as a volcanic product. Los Remoilinos, Guasko, Chili, Peru, Saxony, Vesuvius, Etna.

Connellite.—*Sulphato-chloride of Copper.* **rhombohedral.** *Lus.* vitreous. Translucent. *Col.* blue. B. fusible. Soluble in hydrochloric acid.

Found with arseniate of oxide of copper. Cornwall.

Percylite—*A Hydrochloride of Lead and Copper.* **cubic.** H 2·5. Case 59. *Lus.* vitreous. *Col.* sky-blue. *Str.* the same. Soluble in nitric acid by boiling.

Found with gold in a matrix of quartz. La Sonora in Mexico.

Kerate.—*Muriate of Silver, Hexahedral Perl Kerate, Hornsilver.*—Ag Cl. **cubic.** H 1·0 — 1·5 G 5·55 — 5·60. Case 59. *Frac.* conchoidal. Transparent, translucent on the edges. *Lus.* waxy. *Col.* pearl-gray, blue, green, brown, yellowish-white. *Str.* shining. Malleable and sectile. B. fusible. Soluble in ammonia.

A rare mineral, found in veins with ores of silver. Mexico, Peru, Chili, Siberia, France, Cornwall, the Hartz. Derives its name from *κερας horn*, on occount of its appearance.

Embolite.—2 Ag Br + 3 Ag Cl. **cubic.** H 2·0 G 5·789 — 5·806. *Frac.* hackly. *Lus.* adamantine. *Col.* yellow, green. Perfectly malleable.

Found in limestone. Copiapo in Chili.

Bromite.—*Bromide of Silver.* Ag Br. **cubic.** H 1·0 — 2·0 G 5·8 — 6·0. Case 59. *Lus.* bright. *Col.* green, yellow. *Str.* green. B. fusible. Soluble in warm concentrated ammonia.

Found with kerate. Mexico, Chili, Bretagne.

Iodite.—*Iodic Silver.*—Ag I. H 1·0 G 5·504. *Lus.* resinous. *Col.* yellow, green. *Str.* shining. B. fusible. Soluble in strong hydrochloric acid.

Found in serpentine and porphyry. Mexico, Chili, Spain.

Calomel.—*Muriate of Mercury, Pyramidal Perl Kerate, Horn Quicksilver.*—Hg^2 Cl **pyramidal.** H 1·5 G 6·4 — 6·5. Case 59. *Frac.* conchoidal. Translucent, translucent on the edges. *Lus.* adamantine. *Col.* gray, green, yellow, brown. *Str.* white. Sectile. B. volatilizes. Soluble in nitro-muriatic acid.

Found with mercury and cinnabar. Bohemia, the Palatinate, Carniola, Spain.

Coccinite.—*Ioduret of Mercury.*—*Lus.* adamantine. *Col.* red. Melts and sublimes easily.

This mineral is probably identical with the red crystals of Iodide of Mercury, Hg I, formed by cooling a saturated solution of Iodide of Mercury in an aqueous solution of Iodide of Mercury and Potassium. These crystals are *pyramidal;* when heated they sublime and form yellow crystals belonging to the prismatic system. The yellow crystals become red by being scratched or rubbed.

Mellite.—*Mellate of Alumina, Honey Stone, Pyramidal Melichrone Resin.*—Al O^3 + C^4 O^3 + 18 H O. **pyramidal.** H 2·0 — 2·5 G 1·5 — 1·6. Case 60. *Frac.* conchoidal. Transparent, translucent. *Lus.* resinous. *Col.* Honey-yellow, inclining to red or brown. *Str.* white. Sectile. Soluble in nitric acid.

Found in beds of brown coal. Thuringia, Bohemia, Moravia.

Humboltine.—*Oxalate of Iron, Oxalit.*—2 (Fe O + C^2 O^3) + 3 H O. H 2·0 G 2·15 — 2·25. Case 60. *Frac.* uneven. Opaque. *Lus.* waxy. *Col.* yellow. *Str.* yellow. Slightly sectile. Soluble in acids.

Found in a bed of brown coal. Bohemia, Hessia.

Whewellite.—*Oxalate of Lime.*—Ca O + $C^2 O^3$ + H O. **oblique**. H 2·5 — 3·0 G 1·833. *Frac.* conchoidal. Transparent, opaque. *Lus.* vitreous, colourless. *Str.* white. Very brittle.

Found with calcite. Hungary.

Struvite.—*Guanite.*—(2 Mg O + P O^5) + N H^3 + 13 H O. **prismatic**. H 1·5 — 2·0 G 1·66 — 1·75. Case 60A. *Frac.* conchoidal. Transparent, semi-transparent. *Lus.* vitreous. *Col.* colourless, yellow, brown. *Str.* white. B. fusible. Soluble in hydrochloric acid.

Found in crystals in 1845, when digging the foundation of the new church of St. Nicholas, Hamburgh, having been produced by the decomposition of animal matter; it has also been discovered in guano from the coast of Africa.

Amber.—*Bernstein, Succinite.*—$C^{10} H^8$ O. Amorphous. H 2·0 — 2·5 G 1·0 — 1·1. Case 60. Transparent, translucent. *Lus.* waxy. *Col.* yellow, red, brown, white. *Str.* yellowish-white. Slightly brittle.

Found in rounded masses and disseminated, occurs principally in the tertiary coal formations. Sicily, Prussia, Pomerania, Holstein, Courland, Livonia, Greenland, China, France, Italy, Spain, England, Ireland. It frequently contains insects which are now extinct. Used for ornamental purposes, and also in the manufacture of varnishes.

Copaline.—*Fossil Copal, Highgate Resin.*—Amorphous. H 2·5 G 1·046. Case 60. *Frac.* conchoidal. Semi-transparent, translucent. *Lus.* waxy. *Col.* yellow, brown. Brittle. Slightly soluble in ether.

Found in blue clay. Highgate near London, and in the East Indies.

Retinasphalt.—*Retinite.*—Amorphous. H 1·0 — 2·0 G 1·05 — 1·20. Case 60. *Frac.* conchoidal. Semi-transparent, opaque. *Col.* yellow, brown, gray. *Str.* yellowish-brown. Brittle.

Found in brown coal, stone coal and peat. Halle, Vogelsgebirge, Devonshire, Maryland, Bohemia, Osnabrück.

Naphtha.—*Earth Oil, Bitumen.* Liquid. G 0·7 — 0·8. Case 60. Transparent, translucent. *Col.* colourless, yellow, brown. Unctuous to the touch. Smell aromatic and bituminous. Soluble in pure alcohol.

Found oozing out of clefts in rocks or the ground. Italy, the Alps, Pyrenees, United States, Persia, East Indies, China, Baku. When exposed to the air becomes thick and at last solid. *Petroleum*, *Elaterite*, and *Asphaltum*, are supposed to be naphtha thus altered.

Petroleum, found in Hanover, Brunswick, Alsace, Auvergne, Barbadoes, Trinidad, Lancashire, Coalbrookdale, Edinburgh, Ava.

Elaterite, found in Derbyshire, France, and Connecticut.

Asphaltum, found in Hanover, Soult, the Rhone, the Dead Sea, Cornwall, Shropshire, East Lothian.

Scheererite.—C H^2. **oblique**. Soft. G 1·0 — 1·2. Case 60. *Frac.* conchoidal. Transparent, translucent. *Lus.* resinous. *Col.* white, gray, yellow, green. *Str.* white. Brittle. Unctuous to the touch. Soluble in nitric acid.

Found in brown coal. St. Gallen, Westerwald.

Konleinite.—*Konlite.*—C^2 H. G 0·88. *Col.* white.

Found in crystalline plates and grains, in brown coal and in a peat bog. Switzerland, Bavaria.

Fichtelite.—A hydrocarbon. Transparent. *Lus.* pearly, colourless. Unctuous to the touch. Without taste or smell. Soluble in ether.

Found in acicular crystals, between the yearly rings of pine stems in a bed of turf. Redwitz, near the Fichtelgebirge.

Hartite.—A hydrocarbon. H 1·0 G 1·046. Case 60. *Frac.* conchoidal. Translucent. *Lus.* fatty, feeble. *Col.* white. Not flexible. Sectile. Soluble in ether.

Found in brown coal. Oberhart in Austria.

Ozokerite.—C H. [H 1·0 G 0·94 — 0·97. *Frac.* conchoidal. *Lus.* waxy. Translucent on the edges. *Col.* green, brown, yellow, red. *Str.* yellowish-white. Sectile, tough and flexible. Soluble in oil of turpentine.

Found in Moldavia, Austria, Newcastle.

Hatchettine.—C H. H 1·0 G 0·6078. Case 60. Translucent, nearly opaque. *Lus.* pearly. *Col.* yellow. Partially soluble in ether.

Found in masses resembling wax or train oil, in the coal formations of England and Scotland.

Middletonite.—G 1·6. Thin fragments, transparent. *Lus.* resinous. *Col.* brown. *Str.* light brown. Soluble in concentrated sulphuric acid.

Found in small rounded masses between layers of coal. Leeds, Newcastle.

Psathyrite.—*Hartin.*—G 1·115. *Col.* white. Soluble in petroleum.

Found in masses resembling train oil in brown coal. Oberhart in Austria.

Guyaquillite.—Amorphous, soft. G 1·092. Opaque. *Col.* bright yellow. Soluble in alcohol.

Found at Guyaquil in South America. A substance found in the Irish bogs, and called *bog butter*, seems to be allied to guyaquillite.

Berengelite.—Amorphous. *Frac.* conchoidal. *Lus.* resinous. *Col.* dark brown. *Str.* yellow. Taste, bitter. Soluble in ether.

Found in large masses in the province of St. Juan de Berengela in South America.

Walchowite.—Amorphous. H 1·5 — 2·0 G 1·035 — 1·069. *Frac.* conchoidal. Translucent. Translucent on the edges. *Lus.* fatty. *Col.* yellow, brown. *Str.* yellowish-white. Brittle. Soluble in sulphuric acid.

Found in brown coal. Walchow in Moravia.

Ixolyte.—Amorphous. H 1·0 G 1·008. Case 60. *Frac.* conchoidal. *Lus.* resinous. *Col.* red. *Str.* yellow. Sectile. Smell, aromatic.

Found in brown coal. Oberhart in Austria.

Piauzite.—H 1·5 G 1·220. *Frac.* imperfect conchoidal. Translucent on the thinnest edges. *Col.* blackish-brown. *Str.* yellowish-brown. Sectile.

Found in a bed of brown coal, near Piauze in Carniola.

Anthracite. H 2·0 – 2·5 G 1·3 – 1·75. Case 60. *Frac.* conchoidal. *Lus.* vitreous. *Col.* black. *Str.* black. Brittle.

Found in the Alps, Pyrenees, France, Pennsylvania, Massachusetts, Bohemia, Silesia, Saxony, Hessia, Staffordshire, Brecknockshire, Carmarthenshire, Pembrokeshire, Scotland, Ireland. Used as a fuel for furnaces.

Black Coal.—*Bituminous coal.* H 2·0 — 2·5. Case 60. *Frac.* conchoidal. *Lus.* waxy. *Col.* black. *Str.* black. Slightly sectile. Brittle.

Found in England, Germany, Bohemia, Moravia, Belgium, France, North America, China, Japan, Australia. Most valuable as a fuel. Upwards of 50,000,000 tons are obtained from the coal fields of England annually.

Brown Coal.—*Lignite.* H 1·0 — 2·5 G 0·5 — 1·5. Case 60. *Frac.* conchoidal. *Lus.* waxy. *Col.* brown, black. *Str.* browu.

Found in Germany, Switzerland, Hungary, Italy, Greece, Iceland, Greenland, Devonshire, Sussex, Scotland, Faroe Isles, Ireland.

WALTER MITCHELL, M.A.

J. TENNANT, F.G.S.

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